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Zooplankton of the Colorado River
Glen Canyon Dam to Diamond Creek

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ZOOPLANKTON OF THE COLORADO RIVER

GLEN CANYON DAM TO DIAMOND CREEK

Aquatic Biology

of the

Glen Canyon Environmental Studies

By

Loren R. Haury
Scripps Institution of Oceanography
La Jolla, California 92093

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Six sets of zooplankton samples from the Colorado River and terminal portions of its major tributaries from Glen Canyon Dam to Diamond Creek (June 1980-October 1986) and five sets from Lake Powell (June 1981-January 1985) were collected. Sixteen of the 33 species of crustaceans found in the river are true plankton, the remainder occasionally occur there as drift. Other invertebrate drift is numerically less important, but appears to comprise the bulk of the total invertebrate biomass transported by the river. Lake Powell is the source of most zooplankton in the Colorado River below Glen Canyon Dam. The mode of discharge and release rate from the dam will determine the kinds and abundance of zooplankton present in the river. River zooplankton is dominated by copepods; cladocerans were always much less abundant except when spillway releases occurred. Abundance did not decrease significantly over the 240 miles between the dam and Diamond Creek, although the % of organisms in poor condition increased with distance below the dam. All life stages were present indicating the potential for active reproduction throughout the river. At high flows populations should be able to persist in terminal pools and backwaters. Several species of fish feed on zooplankton during their larval stage, nothing is known of the importance of the zooplankton-benthic invertebrate-fish foodchain links.

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ABSTRACT

Six sets of zooplankton samples from the Colorado River and terminal portions of its major tributaries from Glen Canyon Dam to Diamond Creek were collected between June 1980 and October 1986. Five additional sets of samples from Lake Powell adjacent to Glen Canyon Dam were taken between June 1981 and January 1985. Sixteen of the 33 species of crustaceans found in the river are true plankton; the remainder occasionally occur there as drift. Other invertebrate drift is numerically less important, but appears to comprise the bulk of the total invertebrate biomass transported by the river. Lake Powell is the source of most zooplankton in the Colorado River below Glen Canyon Dam. The mode of discharge and release rate from the dam will determine the kinds and abundances of zooplankton present in the river. River zooplankton is dominated by copepods; cladocerans were always much less abundant except when spillway releases occurred. Abundance did not decrease significantly over the 240 miles between the dam and Diamond Creek, although the percentage of organisms in poor condition increased with distance below the dam. Females carrying eggs, male copepods with internal spermatophores ready for extrusion, and naupliar stages were present in most samples, indicating the potential for active reproduction throughout the river. At high flows, exchange rates between the mainstream and potential refuges for zooplankton are high. At low flows, populations should be able to persist in terminal pools and backwaters. Several species of native and introduced fish feed on zooplankton during their larval stage; nothing is known of the importance of the zooplankton-benthic invertebrate-fish foodchain links. The proposed alternative release modes, ranked in order from least to greatest estimated impact on the zooplankton component of the aquatic community, are: One, Three, Four, Five, Two. The effects of rare periods of high or low releases cannot be predicted without knowledge of the equilibrium conditions resulting from the alternative chosen. The above results and conclusions are based on restricted spatial and temporal sampling; methodological problems also limited the value of the samples. Further research is needed on: 1) the plankton of Lake Powell, 2) the interaction of dam release mode with the plankton of the lake, 3) quantification of invertebrate drift, 4) zooplankton-benthic invertebrate-fish foodchain links, and 5) persistence of zooplankton in refuges and the mechanisms of exchange between refuges and mainstream.

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Introduction

In unregulated rivers, true plankton are found only in the lower reaches or for short distances below natural lakes (Ward and Stanford 1983). With impoundment, the reservoirs contribute lentic plankton to the river below the dam. Three factors regulate this contribution (Petts 1984): 1) the retention time of waters in the reservoir, 2) the seasonal cycle of the lentic plankton, and 3) the nature of the discharge (e.g., depth of release intakes and the rate of discharge). Thus the plankton found in regulated rivers will be "composed of both true lentic plankton, derived from the reservoir, and plankton supplied by the bed, backwaters, and tributaries, of the river below the dam" (Petts 1984). These factors, both lotic and lentic, result in each impoundment/regulated river reach being a unique system.

From the standpoint of zooplankton ecology, the Colorado River below Glen Canyon Dam is unique in other respects. Most of the river's tributaries, dry except during heavy summer rains, contribute little to its flow and would not be expected to supply zooplankton to the mainstem. The number and severity of the rapids along the course of the river to Lake Mead produce an environment ill-suited for plankton. Natural mortality, the filtering of plankton from the flow by the periphyton (especially the extensive *Cladophora* beds), and predation by other invertebrates and fish, also suggest that zooplankton surviving discharge from Lake Powell should not persist in the river system below for more than a few dozen miles. Some results in the literature,however, suggest that areas of retarded flow (backeddies, terminal pools of tributaries) can serve as loci for endemic populations or as temporary refuges for populations persisting between flooding events (e.g., Shiel and Walker, 1984).

Three interacting factors, then, should be significant in controlling the distribution and abundance of zooplankton in the Colorado River: 1) the distribution and abundance of plankton in Lake Powell, 2) the characteristics of the Glen Canyon Dam discharge regime, and 3) the factors controlling transport and survival of plankton in the river below. Since the residence time of waters in Lake Powell is long relative to life cycles of most zooplankton (mean water retention time of 1.23 years, Gloss et al 1980), dam releases during normal conditions are probably not important in regulating the lake zooplankton populations.

Glen Canyon Dam is a hypolimnial release reservoir with water for the generators drawn from 4.6 m diameter penstock intakes centered at the 1058 m (3470 ft) level (a full pool depth of 70 m). This depth is well below the productive lighted (euphotic) zone and mixed layer under most lighted (euphotic) zone and mixed layer under most conditions. Other release modes are from the jet tube intakes (about 30 m below penstocks) and the spillways (surface to about 5 m). As lake and reservoir plankton occur throughout these depth ranges, and usually show depth preferences depending on species, season, environmental situation, growth stage, time of day, etc. (Hutchinson, 1967), the discharge mode from Lake Powell will have a strong effect on the type and numbers of planktonic organisms released to the river. The magnitude of the release will affect both the withdrawal pattern from the lake (Merritt and Johnson, 1977) and the survival of plankton in the tailwater and below through interactions of river flow with refuges, severity of the rapids, and frequency and structure of backeddies.

Objectives

The initial planning for the plankton portion of the Glen Canyon Environmental Studies in 1984 encompassed the following objectives.

1) Describe the distribution and abundance of zooplankton species in the Colorado River and the terminal portions of its tributaries from Glen Canyon Dam to Diamond Creek.

2) Relate the time and space patterns observed to:
   a) composition and abundance of zooplankton in Lake Powell immediately above Glen Canyon Dam
   b) release mode and discharge rate of water from dam
   c) distance below the dam
   d) the character of the river, e.g. mainstream backeddies, and terminal pools of tributaries.
   e) season

3) From 1 and 2 above identify:
   a) sources of plankton in the Colorado River
      i) Lake Powell
      ii) endemic populations in terminal pools, backeddies
      iii) temporary refuges
   b) factors causing losses to the populations

4) In conjunction with the work of the Arizona Game and Fish Department, establish the importance of plankton to the fish and what limits the plankton food component of their diet.

5) From 1-4 above, assess the impact of fluctuating flows on the ecology of plankton.

With the beginning of field work, carried out principally by the Arizona Game and Fish Department, it became apparent that these objectives could not be completely met because of both sampling and analysis constraints. Therefore only limited sampling was carried out; both areal and temporal (seasonal and daily) scales of sampling were severely curtailed. For example, no samples from Lake Powell above Glen Canyon Dam were taken as a part of the GCES; fortunately sampling there as a part of a Lake Powell zooplankton study by Haury provided some limited data from this critical component of the dam-river system. The lack of significant fluctuating flows at the times of most zooplankton sampling also precluded any significant addressing of the question of their effects, either on the qualities of the discharge from the lake or on downriver effects. Thus objectives 1 and portions of 2 above form the major part of this report that is substantiated empirically; the remaining objectives are addressed on the basis of the limited data available, relevant literature, and speculation.

Methods

All plankton collections used to prepare this report (summarized in Table 1; with data summary in Appendix I) were obtained either during the course of the Glen Canyon Evironmental Studies or by Haury prior to or during the GCES in his informal research on the plankton of the Lake Powell-Colorado River system (e.g., see Haury 1981). The only other study I know of dealing with the plankton of this part of the Colorado River (Cole and Kubly 1976) did not report quantitative data, mainstream sampling locations, and dates of collections.

The samples reported here were taken with plankton nets of various diameters and net mesh sizes (Table 1). The larger meshes undersampled immature stages and some of the small adult crustaceans; small non-crustacean plankton, e.g. rotifers, were only collected with the 83 μm mesh nets. Attempts early in the studies to use Van Dorn bottles were unproductive because of the low numbers of plankton in the river.

Various techniques of net deployment were used, depending on location. Lake samples and river main channel and backeddy samples were taken from boats using surface or repetitive oblique tows. Some collections were made from the river banks; tributary pools (e.g., at Kanab Creek and Little Colorado River) collections were made by casting and retrieving the net across the pools. Depths of tows were difficult to control in the river; where depth information is available it is noted in Appendix I. Samples from above Glen Canyon Dam near the penstock intakes prior to 1984 integrated depths to about 15 m, after 1984 to about 30 m. There is no

Table 1. Summary of zooplankton collections from the Colorado River and above Glen Canyon Dam used in this report.

Date	Number of Samples	River Miles (inclusive)	Nets Used Diam (cm)	Nets Used Mesh (μm)
		Colorado River		
6/19-7/1/80	19	20 to 223	30	212
			30	363
12/30/80-1/1/81	5	-15 to -12	30	363
8/2/84	2	43	13	80
12/19/84-1/17/85	10	-15 to 185	13	80
			13	243
10/7-14/85	6	28 to 194	13	80
11/10-22/85	14	0 to 132	13	80
		Lake Powell at Glen Canyon Dam		
6/25/81	2	-	30	363
11/8-12/82	2	-	30	363
8/24/83	1	-	13	243
7/27/84	4	-	13	243
1/14/85	1	-	13	243

depth stratified information from the lake adjacent to the dam available; the only collections with depth information were reported by Stone and Rathbun (1968, 1969), their closest station being Wahweap Channel. Their maximum sampling depth was about 50 m, so there is no information on plankton abundance in the lake from the depth of the penstock intakes. Stone and Rathbun reported no species information from these tows.

A flow meter (General Oceanics) was used whenever possible to derive volume of water filtered by each tow. During heavy sediment load conditions, the flow meter sometimes jammed; this and occasional times when tow/flow conditions were less than the flow meter threshold resulted in an underestimation of volume filtered. Some volumes of water filtered were calculated from stream flow velocity and length of time the net was in the water or from the length of tow alone. A number of samples are non-quantitative; see Appendix for a listing of all tow conditions and special remarks relevant to each individual collection. All samples were preserved in formalin.

Laboratory analysis consisted of counting either entire or aliquoted samples under a dissecting microscope. When sediments formed a large fraction of the sample volume, organisms and detritus were elutriated from the sediment and collected in a 102 µm mesh funnel. Adult crustaceans were identified to species whenever possible using Pennak (1978) and Ward and Whipple (1959). Confirmation of identification and updating of taxonomic names used Balcer et al. (1984) and Robertson and Gannon (1981). Harpacticoid, calanoid, and cyclopoid copepod nauplii were lumped into one category while immature (copepodid) stages were listed separately. The number of egg-bearing female copepods was counted, as was the numbers of males with internal spermatophores. Crustaceans in poor condition (parasitized by fungus or protists; internal body structures partially or completely lacking; damaged due to decay) were noted. These data are not presented in the appendices because of their extensive nature; they are available from the author on request. Other organisms (i.e., invertebrate "drift": tardigrades, insect larvae, etc.) were only counted near the end of the study (see Appendix I).

Because of the diversity in sampling gear and methods used, the restricted number of collection sites and samples taken, and the inherent high variability of planktonic systems, no extensive statistical analysis of the data has been undertaken. Quantitative comparisons and interpretations are made where possible; all results and conclusions must be viewed in terms of the limitations of the data set.

Results and Discussion

Appendix I presents a summary of all data collected on the Colorado River between Glen Canyon Dam and Diamond Creek. Not listed in this summary are the data on the condition of the zooplankton and the proportions of female copepods carrying eggs. These data are presented in the text in summary figures. The zooplankton data used to assess conditions in Lake Powell adjacent to the dam are also not presented in detail here, but are incorporated as summary figures in the following section.

Lake Powell Above Glen Canyon Dam

The five collections taken adjacent to the dam in Lake Powell over the period June 1981 to January 1985 provide an approximation of the seasonal cycle of abundance and composition of the main source of zooplankton to the Colorado River below the dam. Figure 1 shows that total zooplankton abundance varies by about two orders of magnitude from a low in late fall to a late summer peak. Cladocerans were dominant in three of the five sampling periods. Figure 2 provides a clearer picture of the seasonal changes in composition. Not apparent in this figure are the extreme changes that occurred in species composition within taxonomic categories. For example, the June 1981 cladoceran fraction was almost all *Daphnia pulex*, while the August 1983 cladocerans were mostly *Diaphanosoma birgei*. Similar variations occurred within the calanoid copepod fraction; the cyclopoid copepods were always dominated by *Diacyclops thomasi*.

The seasonal variations in abundance and taxonomic composition in Lake Powell should be reflected in the plankton found below the dam (e.g., Cowell 1967; Armitage and Capper 1976), with additional shorter time-scale variations introduced by variations in discharge rate (resulting from changes in withdrawal current structure, Merritt and Johnson 1977; see also Matter et al 1983), depth of release (whether penstock, jet tubes, or spillways), and the interaction of the depth of organisms as affected by diel vertical migration (DVM) and the depth of release intakes. These last two factors are strongly species dependent, since depth preferences and vertical migratory behavior varies according to species (Hutchinson 1967). While depth preference and migrations are highly variable within and between species, it would be expected that calanoids (perhaps less so for cyclopoids), which usually undergo daily migrations that vary according to season, would have a marked day-night cycle in release rate. Maximum releases to the river would be during the day when the animals were at depth in the vicinity of the penstock intakes. During spillway operation, the night time release would be high. Cladocerans, which usually have a

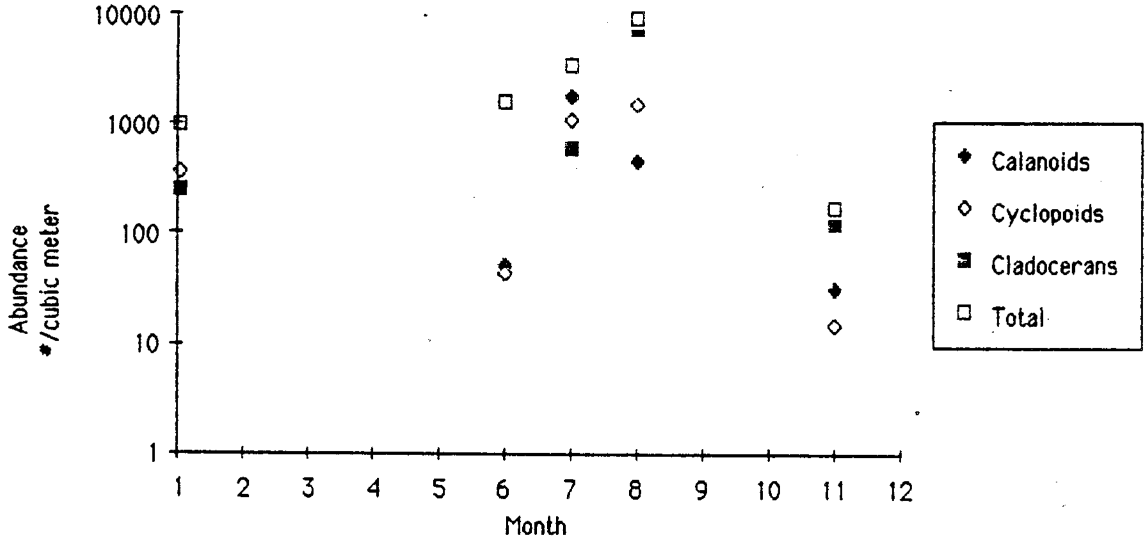

Figure 1. The seasonal cycle of abundance of zooplankton in Lake Powell adjacent to Glen Canyon Dam. Note the log scale of abundance.

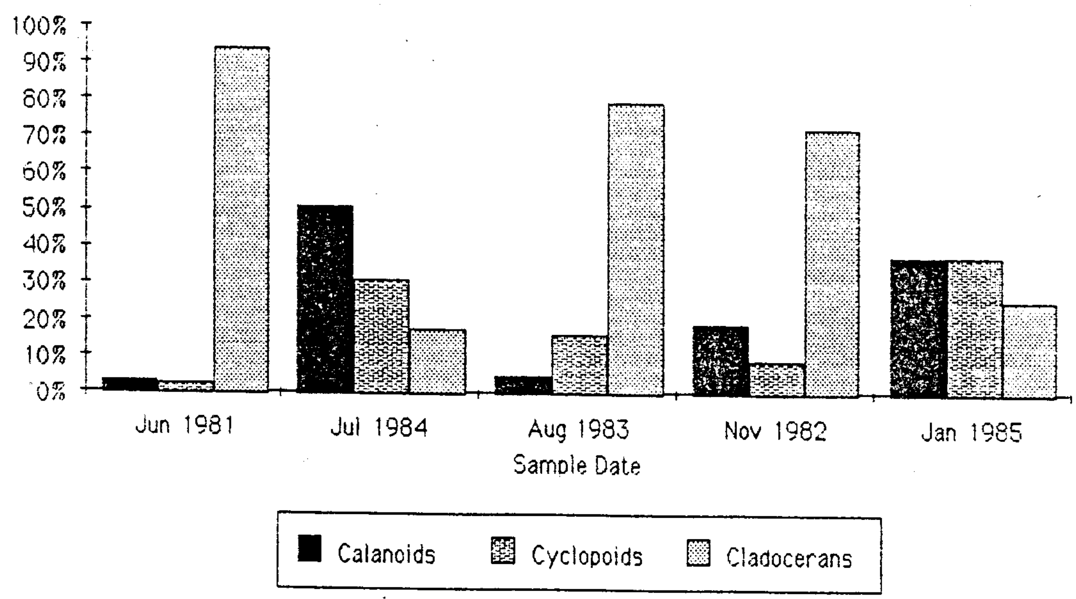

Figure 2. The seasonal variation in composition of zooplankton in Lake Powell adjacent to Glen Canyon Dam.

shallower depth distribution and more restricted migration pattern, should be least affected by penstock releases and most affected by spillway releases. Since little is known about the depth distribution of species during any time of the year in Lake Powell, no quantitative or definite conclusions can be drawn. Clearly, an important objective of any future work should be to obtain this information so that significant effects of discharge on river plankton can be identified and reasonable models developed to predict these effects.

Colorado River: Glen Canyon Dam to Diamond Creek

1) Composition

Table 2 summarizes the species of crustaceans known or potentially able to be present in the plankton in the Colorado River between Glen Canyon Dam and Diamond Creek. Except for some of the benthic ostracods, cyclopoid copepods, and cladocerans, all species have been found in the plankton of Lake Powell.

Samples were obtained on four of the six collecting trips at four or more distances down river. From this limited data set, only a few comments can be made regarding the taxonomic composition of the samples, both as a function of distance down the river and in relation to season of sampling and flow. Figures 3 and 4 present the available data from these four series of samples; composition is expressed as percentages of total abundance made up of calanoid and cyclopoid copepods and cladocerans. In terms of individual species, dominant among the calanoids were Skistodiaptomus pallidus and Leptodiaptomus ashlandi; Diacyclops thomasi was always dominant among the cyclopoids, and Daphnia galeata among the cladocerans. These species are usually numerically important as well in Lake Powell.

In general, calanoid copepods occurred in the highest percentage in all samples except the November 1985 collections, when cyclopoids were dominant in 12 of the 14 samples. Cladocerans were always the least abundant of the taxa except for during the summer of 1980. The samples taken then with a high percentage of cladocerans appear to be related to the times of spillway releases. This is to be expected, since cladocerans occur in the greatest abundance near the surface (upper 10 - 20 meters) and would be most susceptible to release by the spillways.

No relationship between distance down river and proportions of taxa is apparent in the data. Selective removal of taxa has been shown in certain systems (Petts 1984), with body characteristics (size, shape, and strength) and swimming ability being the critical factors; the data reported here do not show these effects.

Table 2. Species of crustaceans found in the Colorado River and terminal portions of its tributaries between Glen Canyon Dam and Diamond Creek. Species or categories marked with an asterisk are true plankters, all occurring in Lake Powell; the remainder are normally benthic and are only occasionally found in the plankton of the river. Compiled from GCES collections, Haury (1981), and Cole and Kubly (1976).

Copepods

Calanoids*

Aglaodiaptomus clavipes
Aglaodiaptomus forbesi
Leptodiaptomus ashlandi
Leptodiaptomus sicilis?
Skistodiaptomus pallidus
Skistodiaptomus reighardi

Cyclopoids

Acanthocyclops vernalis*
Diacyclops thomasi*
Eucyclops agilis
Eucyclops speratus
Mesocyclops edax*
Paracyclops fimbriatus poppei
Tropocyclops prasinus mexicanus*

Cladocerans

Alona affinis
Alona guttata
Bosmina longirostris*
Chydorus sphaericus*
Daphnia galeata mendotae*
Daphnia parvula*
Daphnia pulex*
Diaphanosoma birgei*
Leydigia quadrangularis
Pleuroxus aduncus
Pleuroxus denticulatus

Amphipods

Gammarus lacustris

Ostracods

Cypridopsis vidua
Cyprinotus incongruens
Cyprinotus pellucidus
Cyprinotus salinus
Herpetocypris reptans
Ilyocypris bradyii
Paracandona euplectella
Potamocypris sp.

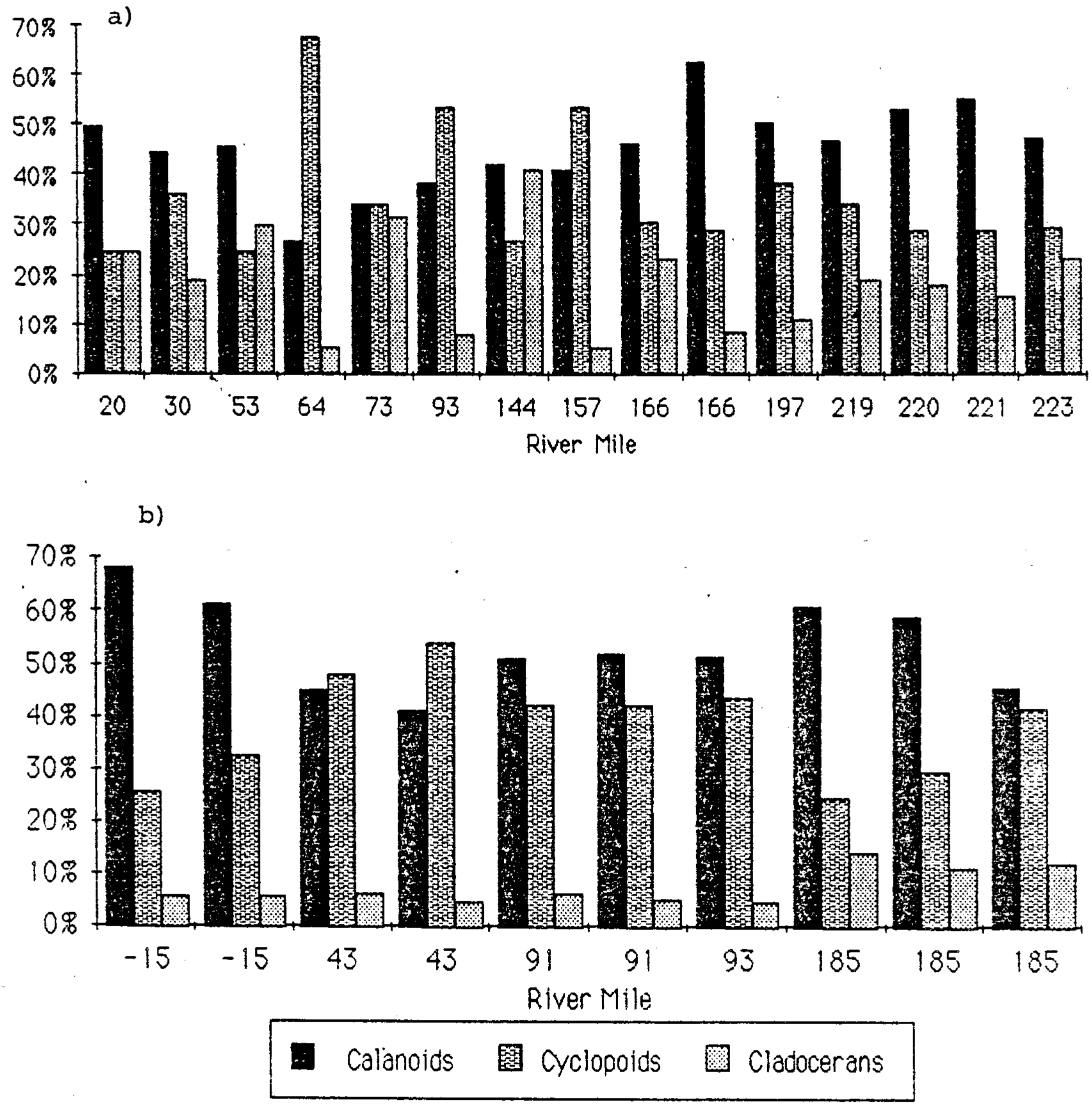

Figure 3. Percent composition of the zooplankton in the Colorado River mainstream as a function of river mile between Glen Canyon Dam and Diamond Creek; a) Summer 1980; b) Winter 1984-85.

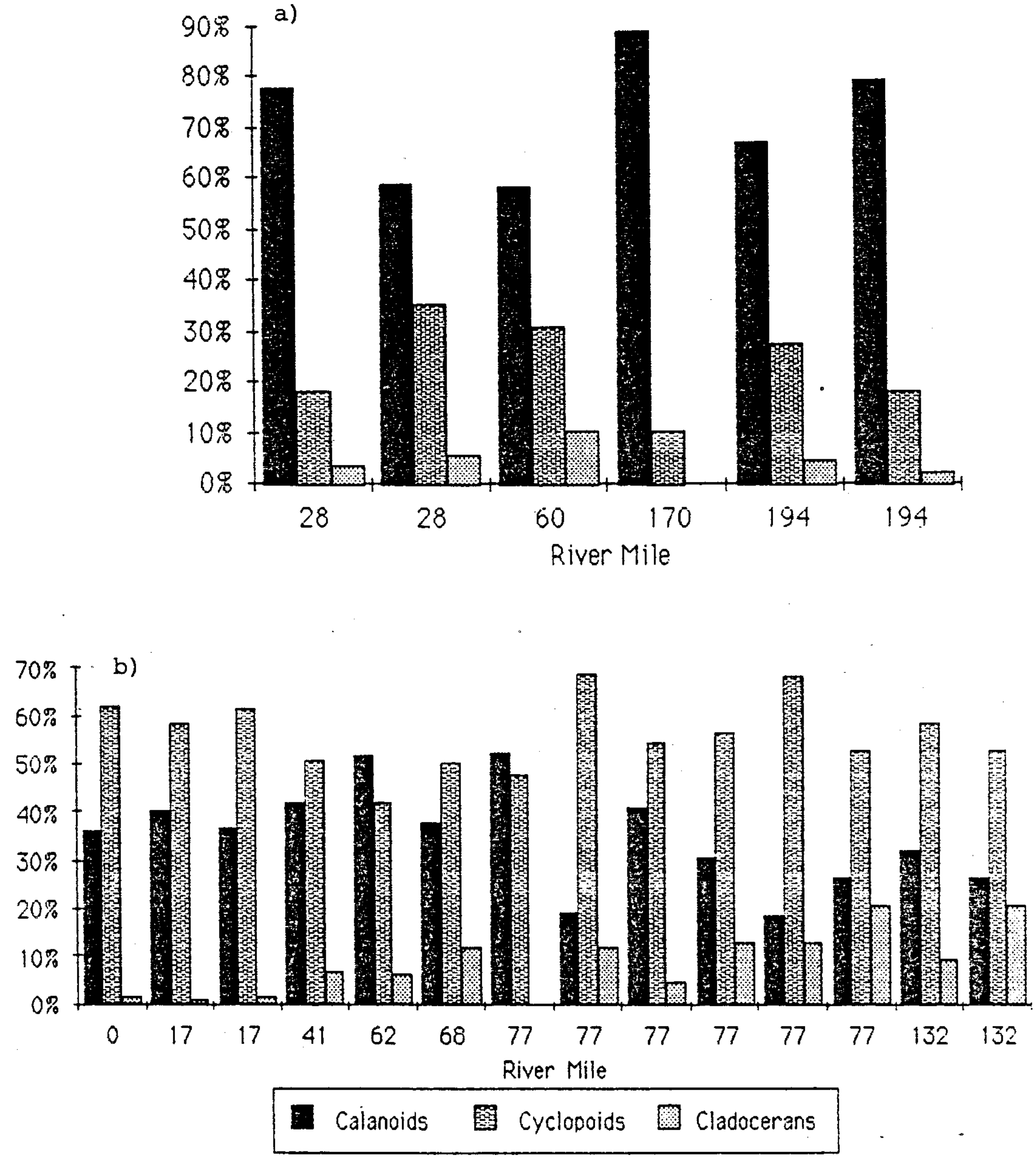

Figure 4. Percent composition of the zooplankton in the Colorado River mainstream as a function of river mile between Glen Canyon Dam and Diamond Creek; a) October 1985; b) November 1985.

2) Abundance

In none of the individual sample sets is there any clear evidence of a decrease in abundance of any taxonomic category or species with distance down river below Glen Canyon Dam. Figure 5 summarizes this result by illustrating the abundance of organisms of all categories from all collections as a function of river mile. The slight increase in abundance with mile indicated by the regression equation is not significant and may result from the high abundances below mile 140 which occurred during June 1980 due to high flows and spillway releases (see Figure 6 and discussion below). The lack of relationship between abundance and distance was not expected. Hynes (1970) provides an extensive discussion of the decrease of plankton abundance usually found with distance below reservoirs. More recent specific examples of distance effects are Armitage and Capper (1976) and Ward (1975). Why the Colorado is different is not clear. The limitations of the sampling program allows no direct comparison of main channel abundance with potential refuges or other sources of supply to the river that might be independent of the Lake Powell contribution. There is some evidence (see Condition and Reproduction sections below) that Lake Powell plankton is able to survive the passage down the 240 mi (386 km) to Diamond Creek with only small mortality. If this result is true, then Lake Powell zooplankton discharges, as modified by the river, have the potential of interactings with endemic resources (e.g. benthic invertebrates, fish spawning and nursury areas) throughout the length of the river to Lake Mead. In fact, Lake Powell discharges could have a significant effect on the plankton of Lake Mead, at least its upper reaches (see Paulson et al. 1980 for a summary of Lake Mead zooplankton ecology), and the kinds of effects discussed by Cowell (1970) are possible.

Discharges from Glen Canyon Dam during three of the six sampling periods on the Colorado River below the dam are illustrated in Appendix II. Sampling points are indicated on these figures, along with the river mile where the samples were taken. Discharges for the August 1984 sampling period, nearly constant at 25,000 cfs (700 m^3/sec), and for the January 1981 nonquantitative samples, are not shown. As no model of how to predict time lag and flow rate at any particular river mile as a function of dam discharge was available to me, no attempt has been made to estimate actual flow at the time of sampling and relate it to the dam discharge causing it. The greatest flow variations during any sampling period occurred during June 1980 (Figure 6) when the spillways were tested for the first time after the filling of Lake Powell. Figure 7 shows the abundances of the three important taxonomic categories as a function of river mile, which approximates a time series equivalent to the discharge figure. Except for the high abundances of copepods at Mile 64, the high numbers from Mile 144 and below are

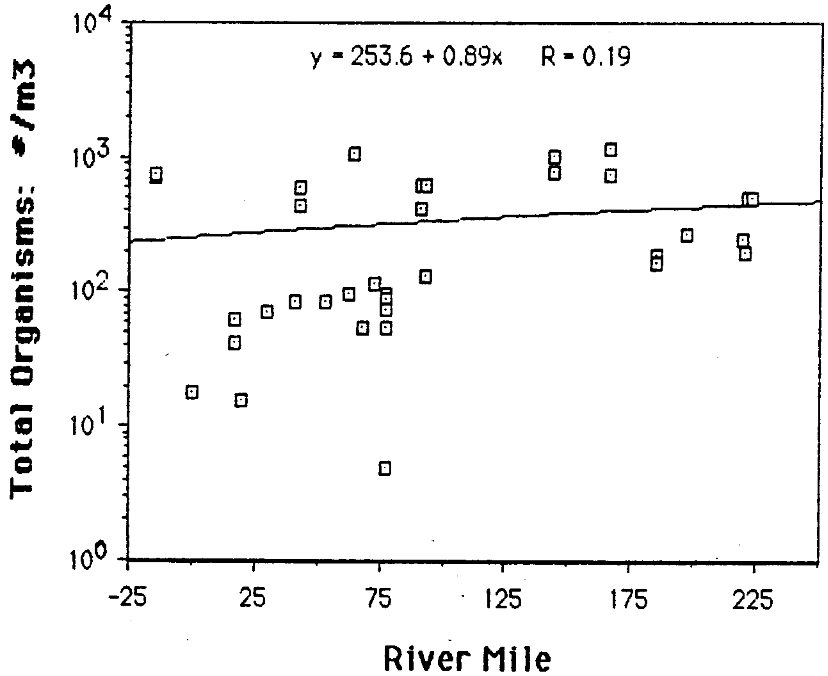

Figure 5. Abundance of all organisms caught in the plankton of the mainstream Colorado River between Glen Canyon Dam and Diamond Creek as a function of river mile. Data from all collections; note log scale of abundance. The correlation coefficient of the regression equation is not significant ($p > 0.2$, t-test).

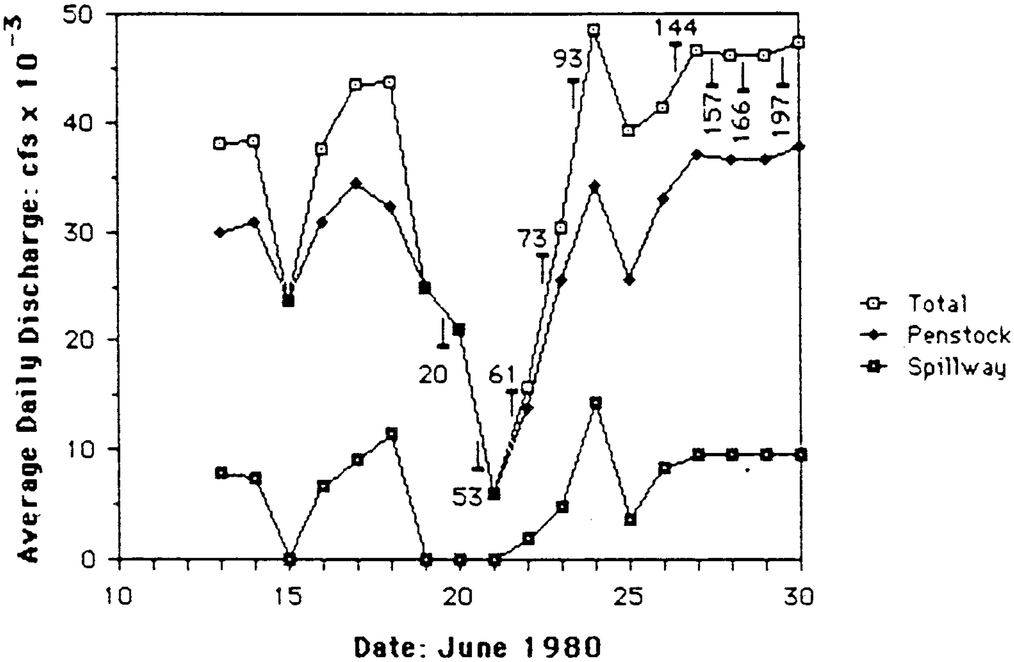

Figure 6. Average daily discharge from Glen Canyon Dam from 13 to 30 June 1980. Times of sampling are noted by the T-shaped symbol together with the river mile of each collection.

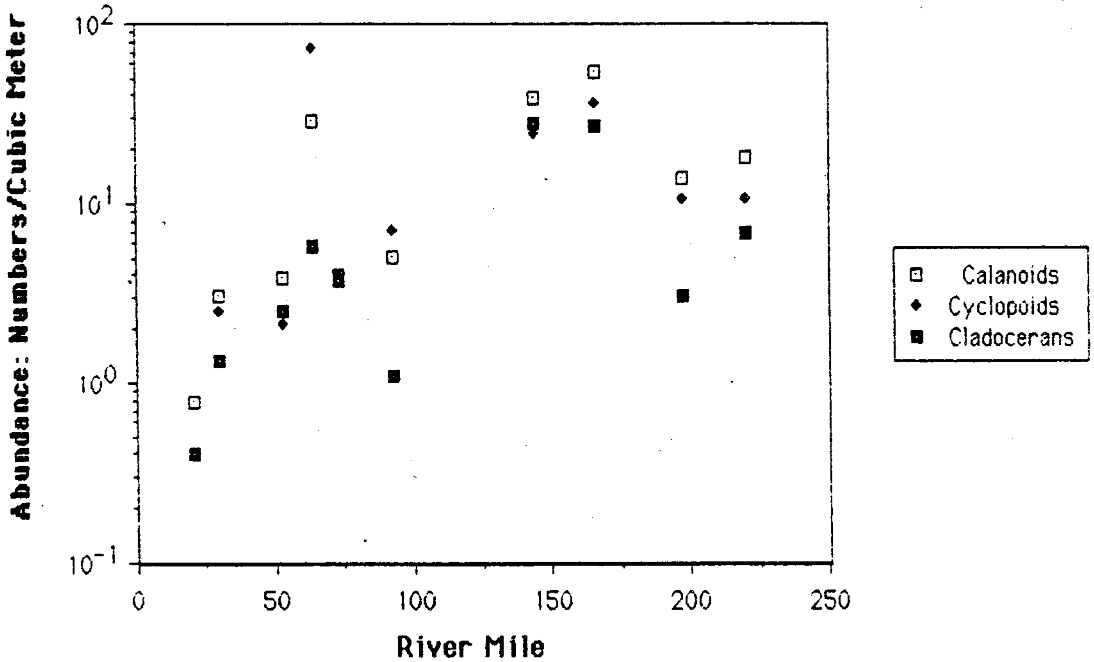

Figure 7. Abundance of three taxonomic categories plotted against river mile for the June 1980 mainstream Colorado River collections. The Mile 144 data are the mean of two samples; the Mile 220 data are the mean of 4 samples taken between Miles 219 and 223. Note the log scale of abundance.

from Mile 144 and below are concordant with the high releases following 23 June. If all other factors were constant, an increase in discharge should not change the abundance of plankton in terms of density (numbers per unit volume of water); increases in density can occur only through release of waters with a higher density of organisms. This probably occurred with the contribution of the spillway releases which removed water from the surface waters of the lake and probably contain the highest abundances (Stone and Rathbun 1968, 1969).

During no other collecting period was sampling intensity sufficient to obtain further information on the relation of flow to abundance except for a series of five samples taken over 20 hours above Hance Rapids on the November 1985 trip. Figure 8 shows the hourly discharge from the dam over the 72 hours surrounding the sampling period (Figure 3, Appendix II shows the discharges for the entire trip). Figure 9 shows the variation in total numbers of organisms caught as a function of time; the apparent cycle may be related to the discharge rate (affecting entrainment levels at the intakes), to the day-night cycle of light affecting abundance (because of DVM), or may be fortuitous, given the high variability of plankton samples. The change in abundance of a factor of two is probably well within the error limits of a single sample. Variations in numbers of organisms within taxonomic categories (not shown) in general matched the variation in total numbers (i.e., species proportions remained relatively constant over the 20 hours of sampling).

As noted in the Methods section, non-crustacean invertebrate drift (e.g., insect larvae, tardigrades, hydra) were not quantified until late in the sampling program. The data available (Appendix I) confirm the general impression gained from all sampling periods that the drift was usually less important numerically than the true zooplankton. Because the drift was usually larger than the zooplankton (especially the insect larvae), however, it contributed the major fraction of the biomass being carried downstream. The quieter conditions in backeddies and terminal pools apparently allowed settling out of the drift, so it was less important in these environments.

3) Condition

The same factors which suggest that abundance should decrease markedly with distance down river from the dam would also be expected to have a visible effect on the condition of organisms captured. While no decrease in abundance was apparent (see above), a significant change in condition with river mile was noted. Figure 10 summarizes all collection data for copepods and shows how as much as 25% of the total number of copepods found near Diamond Creek could be in poor condition (see Methods for definition). Cladocerans have not

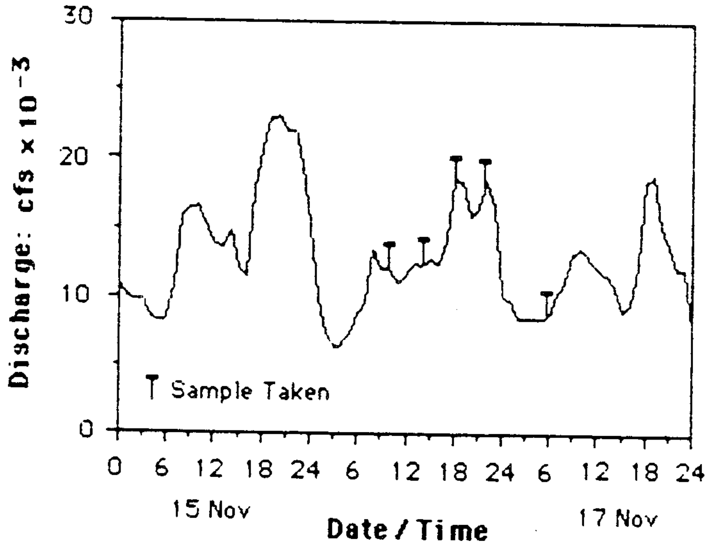

Figure 8. Hourly discharges from Glen Canyon Dam penstocks between 15 and 17 November 1985. The five samples taken above Hance Rapid are noted by the T-shaped symbols.

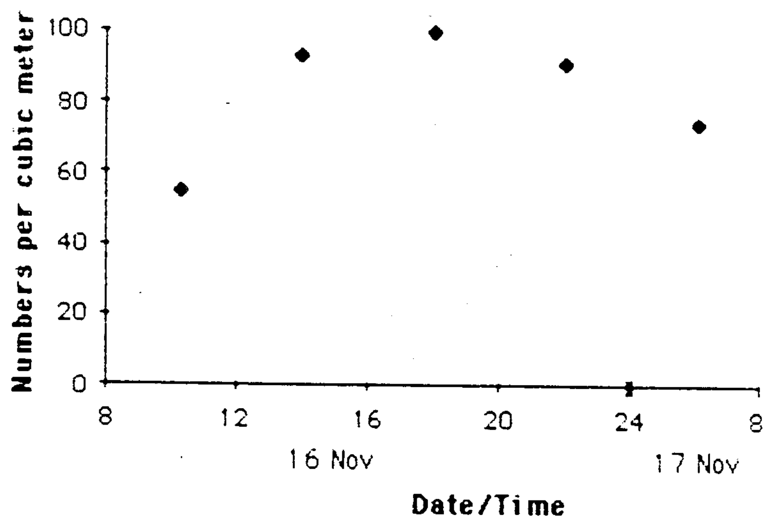

Figure 9. Variation in total numbers of organisms caught above Hance Rapids as a function of sampling time. High water occurred at about 1400, then fell to a level which remained constant between 2200 and 0600.

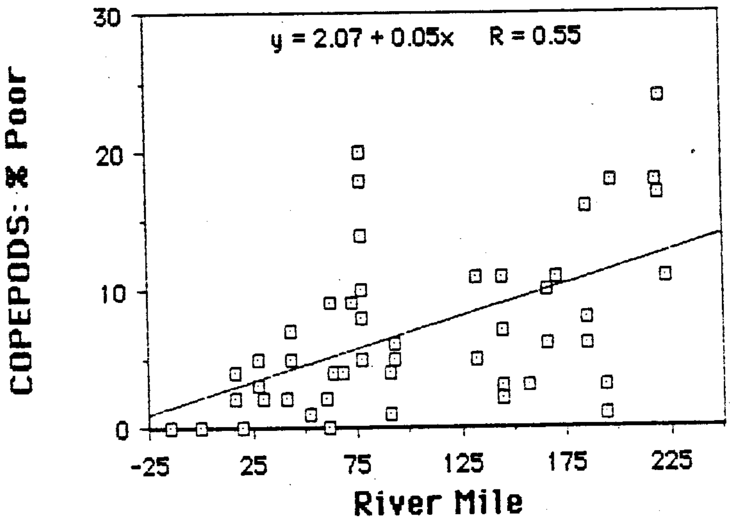

Figure 10. Percent of copepods in poor condition plotted against river mile using data from all collections. The correlation coefficient of the regression equation is significant ($p < 0.01$, t-test).

been included in this analysis because their soft body character resulted in difficulties in distinguishing between "natural" deterioration and damage caused by collection and analysis. The discussion of abundance versus river mile (Figure 5) included individuals in poor condition; if the mortality suggested in Figure 10 for copepods is applied to the regression of Figure 5 for all organisms, a slight, and still not significant, negative relationship results.

4) Reproduction

Reproduction occurs throughout the year in Lake Powell in most of the numerically important species, with a minimum of activity in the winter (Haury, unpublished data). Egg-bearing females and male copepods with spermatophores ready for extrusion were found throughout the river below the dam on all sampling trips; Figure 11 summarizes the egg-bearing female data for the copepod fraction. Not shown, but evident in Appendix I, are the high abundances of naupliar stages in some of the samples. This indicates survival of these stages in Lake Powell releases and possible hatching of eggs from river populations.

Whether the reproductive activity observed occurs solely among Lake Powell discharged plankton in the course of their transit down the river or is a product of losses from endemic or refuge populations is not known. The June 1980 collections provide the only samples where direct comparisons between main channel and potential refuges (backeddies, terminal pools) can be made. The boxed data points in Figure 12 show the remarkable agreement between the percent of egg-carrying females in refuges and in the mainstream. This strongly suggests that the exchange rate is high enough between the pools/backeddies and mainstream to maintain uniform population characteristics. The high releases of late June, occurring when all the comparative samples were taken (Figure 6), may have caused this situation and lower flows may permit other, more isolated conditions to exist in refuges. Further discussion of this point follows in the next section.

5) Endemic and refuge populations

The samples presented above are the only ones where comparisons were possible between main channel transient populations and potential resident populations in backwaters and terminal pools. As suggested, the exchange rate appears to be high, at least under the release conditions (40,000+cfs) preceding and during sampling. This inference is also supported by agreement in the percent of animals in poor condition between the mainstream and possible refuges. Thus high releases appear to effectively reduce the residence time of water (and organisms not able to counter the flow) to a point where no difference in copepod population structure can be detected.

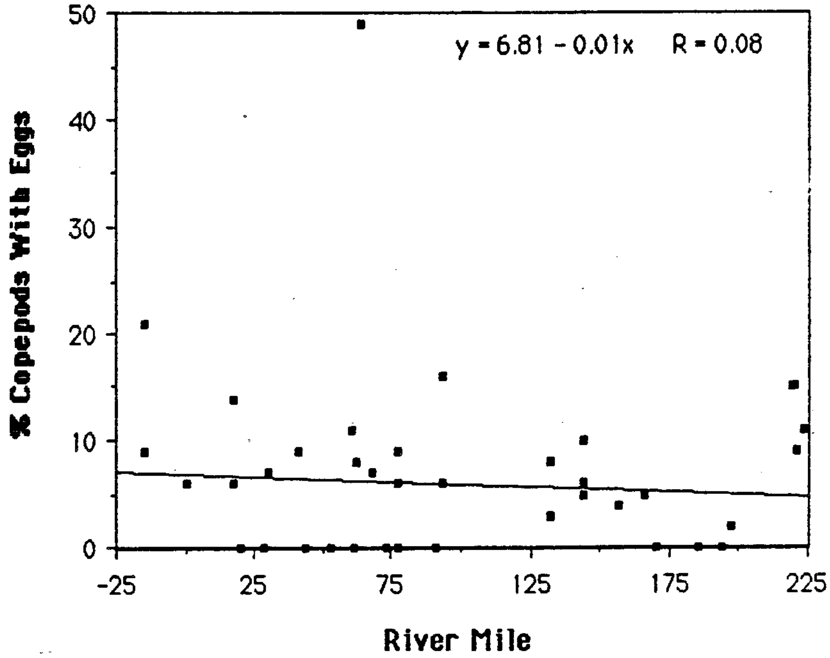

Figure 11. Percent of female copepods carrying egg sacs plotted against river mile using data from all mainstream collections. The correlation coefficient of the regression equation is not significant ($\underline{p} > 0.5$, $\underline{t}$-test).

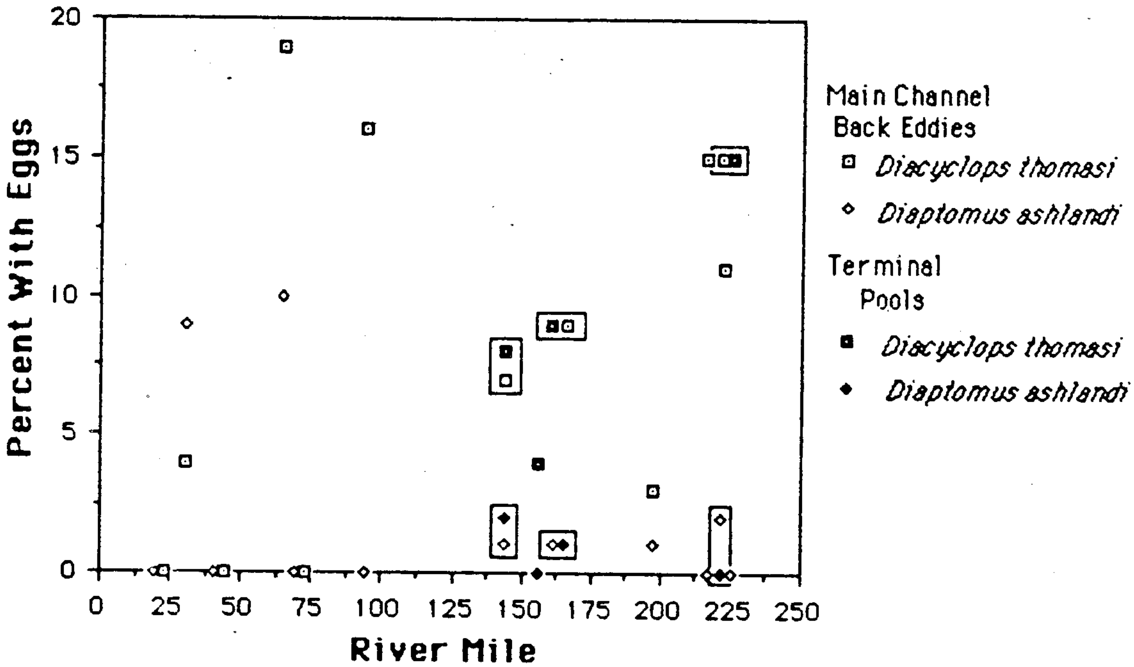

Figure 12. Percent of female copepods carrying egg sacs as a function of river mile; data distinguished by sampling location and species. The boxes enclose points where a direct comparison could be made between adjacent mainstream and terminal pool populations.

At lower flows, the above inferences may not obtain. Barriers to exchange (e.g., sand bars, boulder fields) or longer residence times in eddies may permit persistent populations or at least divergent population characteristics to emerge. Fluctuating flows, and their unpredictable effects on barriers and exchange rates, coupled with naturally occurring high flows, should make it difficult to estimate the importance and occurrence of these populations. Marshes and bar-isolated ponds, if recharged by episodic, rare high flows, should develop populations that will persist.

There appears to be a great deal of natural variation in the suitability of tributary terminal pools for plankton. The Little Colorado River, in the pools behind the bars at its mouth, has been found to have little or no plankton (Cole and Kubly 1976; Appendix I). This is likely to be due to the high carbonate content of the waters. In contrast, Havasu Creek and Kanab Creek terminal pools have abundant plankton.

6) Zooplankton and fish

The results of the Arizona Game and Fish Department studies relating zooplankton and fish are presented in their report. Several comments, however, should be noted here. The gut content studies of AG&F have shown that first-feeding and older larvae of rainbow trout and bluehead and flannelmouth suckers utilize zooplankton as part of their food base. Larvae of other native and introduced fish should also feed on zooplankton (Minckley 1973). During the June 1980 study, adult speckled dace (Rhinichthys osculus) were collected above Tanner Rapids in a backwater (two individuals) and in the Kanab Creek terminal pool (four specimens). No zooplankton were found in the guts of either set of fish.

Hynes (1970) discussed the importance of zooplankton released from reservoirs to the establishment and maintenance of large benthic invertebrate populations below dams. It is not known whether this relationship exists below Glen Canyon Dam, but if it does, as is likely, and assuming the benthic invertebrates and their drift are critical food for larval and adult fish, then the fishes of the river are indirectly tied to the status of the zooplankton.

The humpback chub (Gila cypha) of the Little Colorado River, if they utilize zooplankton during larval and juvenile stages, must apparently forage at the interface between tributary and mainstream waters, as the tributary is depauperate in plankton as well as other invertebrates (see above and Cole and Kubly 1976).

In the National Canyon and Kanab Creek terminal pools, *Daphnia* populations were much reduced (by factors of 4 to 20) compared to adjacent main channel populations. Those occurring in the pools were all small. As the cladocerans are slower swimmers than copepods and were probably in poorer condition, visually-oriented predation by fish feeding selectively on larger, slower individuals may be responsible for these differences. If this observation is valid, the residence time of plankton populations, although short, is still sufficient for the effects of predation to be seen. It also suggests that *Daphnia* may be important as an opportunistic food source for terminal pool predators.

The selective input of Lake Powell zooplankton dependent on dam release mode could provide a means of increasing food to larval fish in the river, especially to the trout populations in the dam to Lee's Ferry reach. Spillway releases at night would draw the highest abundances (both copepod and cladoceran) from the lake. High discharge rates, however, from any release mode might have a detrimental effect on the tailwater populations because of the possibility of washout from the area immediately below the dam (Matter et al 1983).

Operating Criteria

The following comments on the relationship between proposed water release modes from Glen Canyon Dam and the plankton resources of the Colorado River below the dam are made, and should be interpreted, within the following considerations:

1) The crustacean zooplankton data sets are extremely limited in spatial and temporal coverage; the sampling method limitations impose further difficulties in interpreting the results.
2) Adequate information on the distribution, abundance, species composition, and regulating factors for non-crustacean invertebrates of the river and their occurrence in the plankton as drift is not available.
3) The data on the distribution and abundance of zooplankton in Lake Powell is totally inadequate to understand how operations of the dam will effect the "initial conditions" of zooplankton releases to the river.
4) No information was available to me regarding the hydraulics of backeddies, backwaters, and terminal pools in terms of exchange rates (water residence times), how water enters and leaves these areas (e.g., are there two-layer flows, or laterally-regulated exchanges), how these factors change with flow volumes, and how episodic high flows may abruptly alter exchange configurations between periods of relative stasis. Consequently,

judging the effects of various flow regimes is very difficult.

Alternative Number One: Monthly base flow, no daily fluctuation

This is probably the ideal mode for encouraging development of resident zooplankton populations in terminal pools, backeddies, and backwaters by reducing the exchange rate between these areas to a minimum. Periodic (biweekly, monthly?) higher flow rates, especially from spillways, might be valuable in recharging these populations.

Alternative Number Two: Maximized power plant releases

Prime concern with this mode is washout of populations in refuges and possible interference with feeding modes/habits involved in the fish, invertebrate, zooplankton links. Long daily periods of very low flows would also result in a net reduction of habitat where benthic invertebrates and plankton could survive. Extended exposure to dessication of sessile organisms, loss of habitat, and increased predation through concentration of mobile organisms into smaller refuges should decrease standing stocks of most organisms. It is possible that the high penstock releases would entrain more water from a shallower depth in Lake Powell, and thus increase the abundance of plankton for short periods; conversely, the low releases might reduce the numbers delivered to the river through deeper entrainment; a net decrease in total biomass introduced to the river could result.

Alternative Number Three: Restricted minimum and maximum releases

This alternative is closest to the conditions most often encountered during the zooplankton study and resembles the post-1963 conditions. Given the uncertainties in predicting the effects of other flow regimes, this mode should have the least impact on the currently-established river ecosystem. In terms of optimizing the aquatic system's productivity, it would probably have to be ranked behind Alternative Number One.

Alternative Number Four: Recreation season base loaded releases

Same comments as above for Alternative Two for the period of fluctuating flows. The steady June-August flows of 25,000 cfs are about twice the steady flows for the entire year under Alternative 1 and equal to the peak flows of Alternative Three. Releases during 1984-85 had steady flows of this magnitude but sampling intensity during these periods was limited (two samples, August 1984; ten samples during Winter 1984-85, none in backeddies, terminal pools). The lack of data makes it difficult to predict the effects the high Alternative Four flows might have on zooplankton or drift. The shift between extreme fluctuating flows and steady releases might create a long-lasting transition period of hydrology and sediment redistribution that would result in persistent unstable conditions in terminal pools and backwaters detrimental to planktonic and benthic invertebrate, as well as fish, survival and reproduction. The unstable conditions during this period, perhaps amplified by summer runoff episodes, would almost certainly have a negative effect on the river ecology.

Alternative Number Five: Maximized fishery flows

Same comments as for Alternative Four, except that the transition problems might be reduced and the destabilizing effects of episodic flows might not apply. In addition, the somewhat lower releases during this period (in contrast to all other alternatives) would cooccur with the low abundances of plankton in Lake Powell. There might be a reduction in the amount of plankton introduced to the river, with unknown consequences to the food chain.

Alternative Number Six: Rare periods of high release

These periods should cause significant "step function" changes in environments suitable to river plankton that would depend on the "equilibrium" conditions established under the normal release mode. Since what these conditions might be are not known at this time, the effects on the plankton and remainder of the food chain cannot be predicted. The effects of high runoffs on Lake Powell zooplankton abundance (e.g., due to shortened residence times, changes in circulation and chemistry) are also not known, therefore the initial conditions of plankton introduced below the dam cannot be predicted.

Alternative Number Seven: Rare periods of low releases

Transitions to low flow regimes probably will not alter the river morphology which controls environments suitable to river plankton as drastically as Alternative Six conditions might. The consequences of low flow discussed under Alternative Two would probably be more severe, however.

Conclusions

Thirty three species of crustaceans have been found in the Colorado River between Glen Canyon Dam and Diamond Creek; sixteen of these are true members of the plankton, the remainder are normally benthic and are found in the plankton as drift. Lake Powell is the source of most or all of the true zooplankton found in the river below the dam. As a result, the abundance, composition, and depth distribution of Lake Powell zooplankton adjacent to the dam will control the initial conditions of zooplankton introduced to the river. Since little is known about seasonal cycles of abundance and year-to-year variability, and nothing about depth distributions, in the lake, these initial conditions cannot be predicted as a function of yearly and seasonal release demands or daily dam discharge mode.

Although other invertebrates found in the plankton as drift do not usually equal the zooplankton in abundance, they probably constitute the largest fraction of the total invertebrate biomass transported down the river. This does not appear to be true for the quieter parts of the river (backeddies and backwaters) and terminal pools of tributaries, where the drift settles out. There is no information on the quantitative aspects of invertebrate drift in the Colorado River.

The abundance of crustacean zooplankton does not decrease significantly with distance down river from Glen Canyon Dam, although there is a significant increase in the fraction of the population suffering from parasitization, morbidity, and physical damage. Backeddies, backwaters, and terminal pools, all of which can contain abundant zooplankton, may act as refuges for persistent or endemic reproducing populations that contribute to the down river transport. Some data, however, suggest that exchange rates between these areas and the river is high, at least at higher flows, so separate populations may not be important under many conditions. Reproduction goes on throughout the year in Lake Powell and larvae and reproductively-active adults have been found in all environments on the river. Thus, the potential exists for the establishment of viable populations throughout the river to Lake Mead under proper conditions. Backwaters and terminal pools will be the most likely areas populated, but it is not known what flow regimes will permit this to occur.

The zooplankton of the river is dominated by copepods, with calanoids usually more abundant than cyclopoids. Cladocerans were always least abundant except for one sampling period when spillway releases (discharging surface waters where cladocerans are most abundant) made a significant contribution to the total flow of the river. The depth of water release from Lake Powell (penstocks, jet tubes, spillways) should have an important effect on the species composition and abundance because of the presumed differences in vertical distribution of species in the lake. The volume of water discharged, since this affects the depth of entrainment, will also have an effect. No clear relationship, however, between release rate from the dam and abundance and composition could be established because of limited sampling and dam release modes during the study.

Limited data from the Arizona Game and Fish Department show that larval trout and bluehead and flannelmouth suckers feed on zooplankton. Other larval fish species should also be utilizing zooplankton. No concurrent studies, as far as I am aware, were made of zooplankton and larval fish abundance. Adult speckled dace, potential zooplankton predators, in two sets of samples were not feeding on plankton. The lack of information on benthic invertebrates and their drift, and aquatic food chains, makes it difficult to assess whether the zooplankton-benthic invertebrate-larvae/adult fish links are important and how they might be affected by dam operations.

Limited time and space coverage of sampling, problems in sampling methodology, and limited flow regimes encountered during sampling limit the comments that can be made on the effects of the proposed release alternatives. The alternatives are presented here in order of desirability with respect to what is known or can be surmised about zooplankton and their links with the rest of the food chain. Alternative One will be the most likely to result in the development of permanent zooplankton populations in refuges along the river; periodic higher releases from spillways might be of value to encourage these populations. Alternative Three will have the least impact on the presently established ecosystem, but it is not known whether it is an optimum situation. Alternatives Four and Five are similar, with equal negative effects of many months of large fluctuations (see Alternative Three below); Alternative Five should have less impact because of reduced problems associated with the transition from large fluctuating to low or no fluctuation flows. Alternative Two would have the greatest negative impact on zooplankton through the daily repetition of periods of washout and reduction of habitat. The effects of the rare occurrences of high and low flows under the remaining two alternatives cannot be predicted well because it is not known what the "equilibrium" conditions on the river might be at the time. Presumably, high releases would eliminate any resident populations, alter the morphology of the regions where these populations occurred, and reestablishment would be uncertain in these same places. Low flows in drought years would reduce suitable habitat, but probably would not eliminate persistent populations.

Several future studies should be organized around the following objectives in order to obtain an understanding of the aquatic systems of the river adequate to address the question of how to minimize the impacts of dam operations:

1) Describe the seasonal cycle of zooplankton species composition, abundance, reproduction, and vertical distribution in Lake Powell adjacent to Glen Canyon Dam.
2) Develop a model of the interaction of lake zooplankton distributions with withdrawal currents as a function of intake type and discharge rate in order to predict the kinds and amounts of zooplankton introduced to the tailwaters.
3) Quantify the invertebrate drift in the river and its tributaries as a function of season, time of day, and river flow.
4) Determine if the zooplankton-benthic invertebrate-larval/adult fish links in the food chain are important.
5) Establish if persistent populations of zooplankton exist in refuges independent of those transported down the river and how such refuges are affected by exchange rates between them and the mainstream.

Sampling of zooplankton and benthic invertebrates must be integrated into programs addressing fish ecology and the hydrology of eddies, backwaters, and terminal pools; standardized, quantifiable sampling methods must be used.

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APPENDIX I

Summary of data from the six collections of zooplankton taken between Glen Canyon Dam and Diamond Creek between June 1980 and November 1985.

GCES Summer 1980

GCES Summer 1980					
Inclusive Dates	19 Jun 1980	1 Jul 1980			
Trip Agency	NPS/MNA				
River Mile	20	30	53	61	64
Location	North Canyon	Shinumo	Nankoweap	In LCR	Below Salt Cave
Position	Mainstream	Eddy fence	Back eddy	Terminal pool	Back eddy
Depth	0-1 meter	0-2 meters	0-1 meters	0-1 meters	0-1 meters
Date	19-Jun-80	19-Jun-80	20-Jun-80	21-Jun-80	21-Jun-80
Time	9:00	13:00	15:10	12:30	17:00
Volume Filtered m3*	5	8.9	11.7	5.5	3
TAXA/SPECIES #/m3				Abundance in numbers c	
Copepods					
Calanoids					
Nauplii	Not counted	Not counted	Not counted	Not counted	Not counted
Calanoid Unidentified					
Diaptomus imm.	Not counted	Not counted	Not counted	Not counted	Not counted
Diaptomus unid.					
Aglaodiaptomus clavipes m			0.34		0.67
Aglaodiaptomus clavipes f	0.20	0.34	0.43		0.67
Aglaodiaptomus forbesi m					
Aglaodiaptomus forbesi f					
Leptodiaptomus ashlandi m		0.34	0.51		4.33
Leptodiaptomus ashlandi f	0.60	2.47	2.65		23.70
Skistodiaptomus pallidus m					
Skistodiaptomus pallidus f					
Skistodiaptomus reighardi m					
Skistodiaptomus reighardi f					
Leptodiaptomus sicilis?					
Total Calanoids	0.80	3.15	3.93		29.37
Cyclopoids					
Cyclopoid immatures	Not counted	Not counted	Not counted	Not counted	Not counted
Cyclopoid Unident					
Acanthocyclops vernalis					
Diacyclops thomasi	0.40	2.58	2.14		74.00
Eucyclops agilis/speratus				0.36	
Mesocyclops edax					0.33
Paracyclops fimbriatus poppei					
Total cyclopoids	0.40	2.58	2.14	0.36	74.33
Harpacticoids (Unidentified)	Not counted	Not counted	Not counted	Not counted	Not counted
Cladocerans					
Cladoceran unidentified					0.07
Cladoceran immatures	Not counted	Not counted	Not counted	Not counted	Not counted

GCES Summer 1980

Alona affinis			0.02		
Alona guttata					
Bosmina longirostris					
Chydorus sphaericus					
Daphnia unidentified					
Daphnia galeata mendotae					
Daphnia parvula					
Daphnia pulex	0.40	1.35	2.56		5.67
Diaphanosoma birgei					
Leydigia quadrangularis					0.03
Pleuroxus aduncus					
Pleuroxus denticulatus					
Total cladocerans	0.40	1.35	2.58		5.77
Amphipods					
Gammarus lacustris	Not counted	Not counted	Not counted	Not counted	Not counted
Other					
Hydras	Not counted	Not counted	Not counted	Not counted	Not counted
Large insect larvae	Not counted	Not counted	Not counted	Not counted	Not counted
Ostracods	Not counted	Not counted	Not counted	Not counted	Not counted
Rotifers	Not counted	Not counted	Not counted	Not counted	Not counted
Tardigrades	Not counted	Not counted	Not counted	Not counted	Not counted
Molluscs					
Total Organisms	1.60	7.08	8.65	0.36	109.47

GCES Summer 1980

GCES Summer 1980					
Inclusive Dates					
Trip Agency					
River Mile	73	93	144	144	144
Location	Unkar	Granite	Kanab Creek	Bypass channel	Kanab Creek
Position	Mainstream	Mainstream	Bypass channel	Bypass channel	Terminal pool
Depth	0-4 meters	0-3 meters	Surface	Surface	0-1 meters
Date	22-Jun-80	23-Jun-80	26-Jun-80	26-Jun-80	26-Jun-80
Time	17:00	15:00	13:00	14:15	15:00
Volume Filtered m3*	7.2	5.4	13.8	7.7	4.6
TAXA/SPECIES #/m3					
Copepods					
Calanoids					
Nauplii	Not counted	Not counted	Not counted	Not counted	Not counted
Calanoid Unidentified					
Diaptomus imm.	Not counted	Not counted	Not counted	Not counted	Not counted
Diaptomus unid.					
Aglaodiaptomus clavipes m		0.19	0.51	0.52	
Aglaodiaptomus clavipes f	0.28	0.37	1.20	2.30	0.43
Aglaodiaptomus forbesi m					
Aglaodiaptomus forbesi f					
Leptodiaptomus ashlandi m	0.42	0.74	10.20	11.60	59.30
Leptodiaptomus ashlandi f	3.33	3.89	18.20	34.40	67.60
Skistodiaptomus pallidus m					
Skistodiaptomus pallidus f					
Skistodiaptomus reighardi m					
Skistodiaptomus reighardi f					
Leptodiaptomus sicilis?					
Total Calanoids	4.03	5.19	30.11	48.82	127.33
Cyclopoids					
Cyclopoid immatures	Not counted	Not counted	Not counted	Not counted	Not counted
Cyclopoid Unident					
Acanthocyclops vernalis					
Diacyclops thomasi	4.03	7.04	22.30	27.40	103.20
Eucyclops agilis/speratus					0.22
Mesocyclops edax		0.19	0.36	0.13	
Paracyclops fimbriatus poppei					
Total cyclopoids	4.03	7.23	22.66	27.53	103.42
Harpacticoids (Unidentified)	Not counted	Not counted	Not counted	Not counted	Not counted
Cladocerans					
Cladoceran unidentified			0.04		
Cladoceran immatures	Not counted	Not counted	Not counted	Not counted	Not counted

GCES Summer 1980

Alona affinis					
Alona guttata					
Bosmina longirostris					
Chydorus sphaericus					
Daphnia unidentified					
Daphnia galeata mendotae					
Daphnia parvula					
Daphnia pulex	3.75	1.11	28.10	28.40	1.30
Diaphanosoma birgei					
Leydigia quadrangularis					
Pleuroxus aduncus					
Pleuroxus denticulatus					
Total cladocerans	3.75	1.11	28.14	28.40	1.30
Amphipods					
Gammarus lacustris	Not counted	Not counted	Not counted	Not counted	Not counted
Other					
Hydras	Not counted	Not counted	Not counted	Not counted	Not counted
Large insect larvae	Not counted	Not counted	Not counted	Not counted	Not counted
Ostracods	Not counted	Not counted	Not counted	Not counted	Not counted
Rotifers	Not counted	Not counted	Not counted	Not counted	Not counted
Tardigrades	Not counted	Not counted	Not counted	Not counted	Not counted
Molluscs					
Total Organisms	11.81	13.53	80.91	104.75	232.05

GCES Summer 1980

GCES Summer 1980				
Inclusive Dates				
Trip Agency				
River Mile	144	157	166	166
Location	Kanab Creek	Havasu	Upper National	Upper National
Position	Terminal pool	Terminal pool	Left side	Backwater
Depth	0-1 meters	0-2 meters	0-1 meters	Surface
Date	26-Jun-80	27-Jun-80	28-Jun-80	28-Jun-80
Time	15:15	12:30	7:45	8:30
Volume Filtered m3*	5.7	5.7	5.7	3.2
TAXA/SPECIES #/m3				
Copepods				
Calanoids				
Nauplii	Not counted	Not counted	Not counted	Not counted
Calanoid Unidentified				
Diaptomus imm.	Not counted	Not counted	Not counted	Not counted
Diaptomus unid.				
Aglaodiaptomus clavipes m			0.35	0.31
Aglaodiaptomus clavipes f	0.18	0.18	1.80	0.31
Aglaodiaptomus forbesi m				
Aglaodiaptomus forbesi f				
Leptodiaptomus ashlandi m	22.70	7.74	17.70	16.00
Leptodiaptomus ashlandi f	16.90	12.90	34.90	29.70
Skistodiaptomus pallidus m				
Skistodiaptomus pallidus f				
Skistodiaptomus reighardi m				
Skistodiaptomus reighardi f				
Leptodiaptomus sicilis?				
Total Calanoids	39.78	20.82	54.75	46.32
Cyclopoids				
Cyclopoid immatures	Not counted	Not counted	Not counted	Not counted
Cyclopoid Unident				
Acanthocyclops vernalis				
Diacyclops thomasi	31.20	27.30	36.00	21.30
Eucyclops agilis/speratus				
Mesocyclops edax			0.35	0.31
Paracyclops fimbriatus poppei				
Total cyclopoids	31.20	27.30	36.35	21.61
Harpacticoids (Unidentified)	Not counted	Not counted	Not counted	Not counted
Cladocerans				
Cladoceran unidentified		0.11		
Cladoceran immatures	Not counted	Not counted	Not counted	Not counted

GCES Summer 1980

Alona affinis				
Alona guttata				
Bosmina longirostris				
Chydorus sphaericus				
Daphnia unidentified				
Daphnia galeata mendotae				
Daphnia parvula				
Daphnia pulex	1.05	2.63	27.50	6.26
Diaphanosoma birgei				
Leydigia quadrangularis				
Pleuroxus aduncus				
Pleuroxus denticulatus				
Total cladocerans	1.05	2.74	27.50	6.26
Amphipods				
Gammarus lacustris	Not counted	Not counted	Not counted	Not counted
Other				
Hydras	Not counted	Not counted	Not counted	Not counted
Large insect larvae	Not counted	Not counted	Not counted	Not counted
Ostracods	Not counted	Not counted	Not counted	Not counted
Rotifers	Not counted	Not counted	Not counted	Not counted
Tardigrades	Not counted	Not counted	Not counted	Not counted
Molluscs				
Total Organisms	72.03	50.86	118.60	74.19

GCES Summer 1980

GCES Summer 1980					
Inclusive Dates					
Trip Agency					
River Mile	197	219	220	221	223
Location	Parashont	219 Mile	220 Camp	221 Mile	223 Mile
Position	Right side	Right side	Right side	Mainstream	Mainstream
Depth	Surface	Surface	0-1 meters	Surface	Surface
Date	29-Jun-80	30-Jun-80	30-Jun-80	1-Jul-80	1-Jul-80
Time	12:00	15:00	16:00	8:00	8:15
Volume Filtered m3*	12.3	11.1	6.2	3.3	3.7
TAXA/SPECIES #/m3					
Copepods					
Calanoids					
Nauplii	Not counted	Not counted	Not counted	Not counted	Not counted
Calanoid Unidentified					
Diaptomus imm.	Not counted	Not counted	Not counted	Not counted	Not counted
Diaptomus unid.					
Aglaodiaptomus clavipes m	0.24	0.18			
Aglaodiaptomus clavipes f	0.08	0.72		0.61	0.54
Aglaodiaptomus forbesi m					
Aglaodiaptomus forbesi f					
Leptodiaptomus ashlandi m	4.05	3.87	3.22	7.88	8.37
Leptodiaptomus ashlandi f	9.56	6.75	7.08	19.10	14.90
Skistodiaptomus pallidus m					
Skistodiaptomus pallidus f					
Skistodiaptomus reighardi m					
Skistodiaptomus reighardi f					
Leptodiaptomus sicilis?					
Total Calanoids	13.93	11.52	10.30	27.59	23.81
Cyclopoids					
Cyclopoid immatures	Not counted	Not counted	Not counted	Not counted	Not counted
Cyclopoid Unident					
Acanthocyclops vernalis					
Diacyclops thomasi	10.40	8.28	5.47	14.50	14.60
Eucyclops agilis/speratus					
Mesocyclops edax	0.16	0.18	0.16		0.27
Paracyclops fimbriatus poppei					
Total cyclopoids	10.56	8.46	5.63	14.50	14.87
Harpacticoids (Unidentified)	Not counted	Not counted	Not counted	Not counted	Not counted
Cladocerans					
Cladoceran unidentified					
Cladoceran Immatures	Not counted	Not counted	Not counted	Not counted	Not counted

GCES Summer 1980

Alona affinis					
Alona guttata					
Bosmina longirostris					
Chydorus sphaericus					
Daphnia unidentified					
Daphnia galeata mendotae					
Daphnia parvula					
Daphnia pulex	3.08	4.68	3.54	7.88	11.60
Diaphanosoma birgei					
Leydigia quadrangularis					
Pleuroxus aduncus					
Pleuroxus denticulatus					
Total cladocerans	3.08	4.68	3.54	7.88	11.60
Amphipods					
Gammarus lacustris	Not counted	Not counted	Not counted	Not counted	Not counted
Other					
Hydras	Not counted	Not counted	Not counted	Not counted	Not counted
Large insect larvae	Not counted	Not counted	Not counted	Not counted	Not counted
Ostracods	Not counted	Not counted	Not counted	Not counted	Not counted
Rotifers	Not counted	Not counted	Not counted	Not counted	Not counted
Tardigrades	Not counted	Not counted	Not counted	Not counted	Not counted
Molluscs					
Total Organisms	27.57	24.66	19.47	49.97	50.28

GCES August 1984

GCES August 1984			
Inclusive Dates	2 August 1984		
Trip Agency	Arizona G & F		
River Mile	43	43	
Location	Pres. Harding	Pres. Harding	
Position	Backeddy	MC	
Depth	?	?	
Date	2-Aug-84	2-Aug-84	
Time	1600	1630	
Volume Filtered m3++	0.127	5.8	
TAXA/SPECIES #/m3			
Copepods			
Calanoids			
Nauplii	102	0	
Calanoid Unidentified			
Diaptomus imm.		0.4	
Diaptomus unid.		0.3	
Aglaodiaptomus clavipes m			
Aglaodiaptomus clavipes f			
Aglaodiaptomus forbesi m			
Aglaodiaptomus forbesi f			
Leptodiaptomus ashlandi m		0.3	
Leptodiaptomus ashlandi f	7.9	0.3	
Skistodiaptomus pallidus m		0.2	
Skistodiaptomus pallidus f			
Skistodiaptomus reighardi m			
Skistodiaptomus reighardi f			
Leptodiaptomus sicilis?			
Total Calanoids	110	2	
Cyclopoids			
Cyclopoid immatures	7.9		
Cyclopoid Unident		0.5	
Acanthocyclops vernalis			
Diacyclops thomasi		11	
Eucyclops agilis/speratus			
Mesocyclops edax		0.9	
Paracyclops fimbriatus poppei			
Total cyclopoids	8	12	
Harpacticoids (Unidentified)		0.2	
Cladocerans			
Cladoceran unidentified			
Cladoceran immatures		0.2	

GCES August 1984

Alona affinis			
Alona guttata			
Bosmina longirostris			
Chydorus sphaericus		0.5	
Daphnia unidentified			
Daphnia galeata mendotae			
Daphnia parvula			
Daphnia pulex			
Diaphanosoma birgei			
Leydigia quadrangularis			
Pleuroxus aduncus			
Pleuroxus denticulatus			
Total cladocerans		1	
Amphipods			
Gammarus lacustris			
Other			
Hydras			
Large insect larvae		0.3	
Ostracods			
Rotifers			
Tardigrades		0.3	
Molluscs			
Total Organisms	118	16	
*All organisms in poor condition because of delay in sample preservation			
++ Uncertainty in volumes filtered makes comparisons unreliable			

GCES 1984? Unknown Provenience

GCES Unknown Provenience	**
Inclusive Dates	1984?
Trip Agency	Arizona G&F
River Mile	?
Location	?
Position	?
Depth	?
Date	?
Time	?
Volume Filtered m3*	?
TAXA/SPECIES #/sample	
Copepods	
Calanoids	
Nauplii	374
Calanoid Unidentified	
Diaptomus imm.	187
Diaptomus unid.	
Aglaodiaptomus clavipes m	
Aglaodiaptomus clavipes f	11
Aglaodiaptomus forbesi m	
Aglaodiaptomus forbesi f	
Leptodiaptomus ashlandi m	
Leptodiaptomus ashlandi f	
Skistodiaptomus pallidus m	33
Skistodiaptomus pallidus f	44
Skistodiaptomus reighardi m	
Skistodiaptomus reighardi f	
Leptodiaptomus sicilis?	
Total Calanoids	649
Cyclopoids	
Cyclopoid immatures	110
Cyclopoid Unident	
Acanthocyclops vernalis	
Diacyclops thomasi	99
Eucyclops agilis/speratus	
Mesocyclops edax	44
Paracyclops fimbriatus poppei	
Total cyclopoids	253
Harpacticoids (Unidentified)	
Cladocerans	
Cladoceran unidentified	
Cladoceran immatures	

GCES 1984? Unknown Provenience

Alona affinis	
Alona guttata	
Bosmina longirostris	22
Chydorus sphaericus	
Daphnia unidentified	
Daphnia galeata mendotae	11
Daphnia parvula	
Daphnia pulex	
Diaphanosoma birgei	
Leydigia quadrangularis	
Pleuroxus aduncus	
Pleuroxus denticulatus	
Total cladocerans	33
Amphipods	
Gammarus lacustris	
Other	
Hydras	11
Large insect larvae	11
Ostracods	
Rotifers	22
Tardigrades	11
Molluscs	
Total Organisms	990
**Label dissolved, no other record available	

GCES Winter 1984-85

GCES WINTER 1984-85					
Inclusive Dates	17 Jan 1984		19 Dec 1984	3 Jan 1985	
Trip Agency	NPS		Arizona G & F		
River Mile	-15	-15	43	43	91
Location	GC Dam	GC Dam	Pres Harding	Pres Harding	Horn Creek
Position	Tailrace	Tailrace	*	*	Main Channel
Depth	0-13m	0-13m	Surface	Surface	Surface
Date	17-Jan-85	17-Jan-85	19-Dec-84	19-Dec-84	25-Dec-85
Time	923	936	1220*	1220*	1153
Volume Filtered m3*	2.20	2.70	1.9	1.9	1.2
TAXA/SPECIES #/m3					
Copepods					
Calanoids					
Nauplii	**	**	200	243	297
Calanoid Unidentified					
Diaptomus imm.	176	173	72	88	107
Diaptomus unid.					
Aglaodiaptomus clavipes m	4.9	5.7		4.4	2.7
Aglaodiaptomus clavipes f	4	9.1	1.2		2.7
Aglaodiaptomus forbesi m					
Aglaodiaptomus forbesi f					
Leptodiaptomus ashlandi m	96	61	0.6		2.7
Leptodiaptomus ashlandi f	113	65	3.5	4.4	2.7
Skistodiaptomus pallidus m	24	41	5.3	31	24
Skistodiaptomus pallidus f	84	112	26	22	27
Skistodiaptomus reighardi m					
Skistodiaptomus reighardi f					
Leptodiaptomus sicilis?					
Total Calanoids	502	467	109	150	169
Cyclopoids					
Cyclopoid immatures			41	119	48
Cyclopoid Unident					
Acanthocyclops vernalis					
Diacyclops thomasi	173	211	64	75	78
Eucyclops agilis/speratus					
Mesocyclops edax	16	37	11	4.4	13
Paracyclops fimbriatus poppei					
Total cyclopoids	189	248	116	198	139
Harpacticoids (Unidentified)					
Cladocerans					
Cladoceran unidentified					
Cladoceran immatures					

GCES Winter 1984-85

Alona affinis					2.7
Alona guttata			0.6		
Bosmina longirostris	12	13	8.2	4.4	16
Chydorus sphaericus					
Daphnia unidentified					
Daphnia galeata mendotae	24	3.4	4.7	8.8	2.7
Daphnia parvula	4		2.4	4.4	
Daphnia pulex	4	20			
Diaphanosoma birgei					
Leydigia quadrangularis		6.8			
Pleuroxus aduncus					
Pleuroxus denticulatus					
Total cladocerans	44	43	16	18	21
Amphipods					
Gammarus lacustris					
Other					
Hydras			1.2		2.7
Large insect larvae					
Ostracods					
Rotifers					
Tardigrades			5		5.4
Molluscs					
Total Organisms	735	758	448	609	634
*Labels dissolved, do not know		** Mesh size			
where samples were taken;		too large for			
#/cubic meter based on mean		capture.			
volume filtered; one sample					
missing. Volume filtered for					
all AG&F samples based on					
water velocity estimate					
plus assumption that start-					
stop times are exact.					

GCES Winter 1984-85

GCES WINTER 1984-85					
Inclusive Dates					
Trip Agency					
River Mile	91	93	185	185	185
Location	Horn Creek	Granite	185 Mile	185 Mile	185 Mile
Position	Left Side	Right Side	Right Side	Main Channel	Left Side
Depth	Surface	Surface	Surface	Surface	Surface
Date	25-Dec-85	25-Dec-85	1-Jan-86	1-Jan-85	3-Jan-85
Time	1211	1327	1405	1430	1448
Volume Filtered m3*	2.8	2.7	1.8	0.7	0.7
TAXA/SPECIES #/m3		Abundance in numbers per cubic meter			
Copepods					
Calanoids					
Nauplii	206	279	82	51	63
Calanoid Unidentified					
Diaptomus imm.	75	125	43	44	42
Diaptomus unid.					
Aglaodiaptomus clavipes m				1.5	
Aglaodiaptomus clavipes f					
Aglaodiaptomus forbesi m					
Aglaodiaptomus forbesi f					
Leptodiaptomus ashlandi m	8.3	8.3		5.7	4.2
Leptodiaptomus ashlandi f	2.8	4.2	7.1	2.8	
Skistodiaptomus pallidus m	5.6	17		7.1	
Skistodiaptomus pallidus f	11	29	10.7	4.3	
Skistodiaptomus reighardi m					
Skistodiaptomus reighardi f					
Leptodiaptomus sicilis?					
Total Calanoids	103	184	61	65	46
Cyclopoids					
Cyclopoid immatures	44	83	10.7	15	4.2
Cyclopoid Unident					
Acanthocyclops vernalis					
Diacyclops thomasi	33	67	14	14	38
Eucyclops agilis/speratus					
Mesocyclops edax	5.6	4.2		4.3	
Paracyclops fimbriatus poppei					
Total cyclopoids	83	154	25	33	42
Harpacticoids (Unidentified)	5.6	4.2			
Cladocerans					
Cladoceran unidentified					
Cladoceran immatures					

GCES Winter 1984-85

Alona affinis	2.7				
Alona guttata					
Bosmina longirostris			7.1	11	8.3
Chydorus sphaericus		4.2	7.1	1.5	4.2
Daphnia unidentified					
Daphnia galeata mendotae	8.3	13			
Daphnia parvula					
Daphnia pulex					
Diaphanosoma birgei					
Leydigia quadrangularis					
Pleuroxus aduncus					
Pleuroxus denticulatus					
Total cladocerans	11	17	14	13	13
Amphipods					
Gammarus lacustris					
Other					
Hydras	8.3	4.2	3.6	2	
Large insect larvae					
Ostracods					
Rotifers					
Tardigrades	11	4.2	7.1		
Molluscs					
Total Organisms	427	647	192	164	164
*Labels dissolved, do not know					
where samples were taken;					
#/cubic meter based on mean					
volume filtered; one sample					
missing. Volume filtered for					
all AG&F samples based on					
water velocity estimate					
plus assumption that start-					
stop times are exact.					

GCES October 1985

GCES October 1985			
Inclusive Dates	7-Oct-85	14-Oct-85	
Trip Agency	AG&F		
River Mile	28	28	60
Location	--	--	Above LCR
Position	?	eddy	?
Depth	Surface	Surface?	Surface?
Date	7-Oct-85	7-Oct-85	9-Oct-85
Time	11:45	11:50	13:45
Volume Filtered m3+	?	?	?
TAXA/SPECIES Raw Counts			
Copepods			
Calanoids			
Nauplii	53	27	28
Calanoid Unidentified			
Diaptomus imm. *	28	4	4
Diaptomus unid.			
Aglaodiaptomus clavipes m			
Aglaodiaptomus clavipes f			1
Aglaodiaptomus forbesi m			
Aglaodiaptomus forbesi f			
Leptodiaptomus ashlandi m	14	1	3
Leptodiaptomus ashlandi f	33	5	9
Skistodiaptomus pallidus m			
Skistodiaptomus pallidus f	6		
Skistodiaptomus reighardi m			
Skistodiaptomus reighardi f			
Leptodiaptomus sicilis?			
Total Calanoids	81	10	17
Cyclopoids			
Cyclopoid immatures	3	3	2
Cyclopoid Unident			
Acanthocyclops vernalis			
Diacyclops thomasi	14	3	5
Eucyclops agilis/speratus			
Mesocyclops edax	2		2
Paracyclops fimbriatus poppei			
Total cyclopoids	19	6	9
Harpacticoids (Unidentified)	4	1	
Cladocerans			
Cladoceran unidentified			
Cladoceran immatures			

GCES October 1985

Alona affinis	1		1
Alona guttata			
Bosmina longirostris	1		1
Chydorus sphaericus			1
Daphnia unidentified	2		
Daphnia galeata mendotae		1	
Daphnia parvula			
Daphnia pulex			
Diaphanosoma birgei			
Leydigia quadrangularis			
Pleuroxus aduncus			
Pleuroxus denticulatus			
Total cladocerans	4	1	3
Amphipods			
Gammarus lacustris			
Other			
Hydras			
Large insect larvae	not counted	not counted	not counted
Ostracods			
Rotifers**	present	present	present
Tardigrades	16	7	7
Molluscs			
Total Organisms	177	52	64
+No flow meter used			
*All Diaptomus immatures were very small			
** All rotifers were very small			
Note: Samples were preserved in Whirlpac bags,			
resulting in damage to organisms by squashing			

GCES October 1985

GCES October 1985			
Inclusive Dates			
Trip Agency			
River Mile	170	194	194
Location	Mohawk	--	--
Position	?	Main eddy	Back water
Depth	Surface?	Surface?	Surface?
Date	13-Oct-85	14-Oct-85	14-Oct-85
Time	14:00	10:00	10:15
Volume Filtered m3+	?	?	?
TAXA/SPECIES Raw Counts			
Copepods			
Calanoids			
Nauplii	20	55	64
Calanoid Unidentified			
Diaptomus imm. *	45	21	29
Diaptomus unid.			
Aglaodiaptomus clavipes m			
Aglaodiaptomus clavipes f			
Aglaodiaptomus forbesi m			
Aglaodiaptomus forbesi f			
Leptodiaptomus ashlandi m	9	1	2
Leptodiaptomus ashlandi f	13	7	8
Skistodiaptomus pallidus m			
Skistodiaptomus pallidus f			
Skistodiaptomus reighardi m			
Skistodiaptomus reighardi f			
Leptodiaptomus sicilis?			
Total Calanoids	67	29	39
Cyclopoids			
Cyclopoid immatures	3	2	1
Cyclopoid Unident			
Acanthocyclops vernalis			
Diacyclops thomasi	5	10	7
Eucyclops agilis/speratus			
Mesocyclops edax			1
Paracyclops fimbriatus poppei			
Total cyclopoids	8	12	9
Harpacticoids (Unidentified)	1	1	1
Cladocerans			
Cladoceran unidentified			
Cladoceran immatures			

GCES October 1985

Alona affinis		1	
Alona guttata			
Bosmina longirostris			
Chydorus sphaericus			
Daphnia unidentified		1	
Daphnia galeata mendotae			
Daphnia parvula			
Daphnia pulex			
Diaphanosoma birgei			
Leydigia quadrangularis			1
Pleuroxus aduncus			
Pleuroxus denticulatus			
Total cladocerans	0	2	1
Amphipods			
Gammarus lacustris			
Other			
Hydras			
Large insect larvae	not counted	not counted	not counted
Ostracods			
Rotifers**	present	present	present
Tardigrades	10	8	5
Molluscs			
Total Organisms	106	107	119

GCES November 1985

GCES November 1985					
Inclusive Dates	10 Nov 1985	22 Nov 1985			
Trip Agency	USGS				
River Mile	0	17	17	41	62
Location	Lee's Ferry	House Rock	House Rock	Buck Farm	Below LCR
Position	Right/ raft	Right/ rocks	Right/ rocks	MC/ raft	Right/rocks
Depth	0-2 meters	Surface	Surface	0-2 meters	0-1 meter
Date	10-Nov-85	11-Nov-85	11-Nov-85	14-Nov-85	15-Nov-85
Time	9:50:00	8:53:00	9:19:00	15:37:00	12:32
Volume Filtered m3*	8.93	2.56	1.27	1.97	0.98
TAXA/SPECIES #/m3					
Copepods					
Calanoids					
Nauplii				12.69	9.18
Calanoid Unidentified					
Diaptomus imm.	0.34	3.52	1.57	3.55	4.08
Diaptomus unid.					
Aglaodiaptomus clavipes m	0.11			0.51	
Aglaodiaptomus clavipes f		0.39	0.78	0.51	1.02
Aglaodiaptomus forbesi m					
Aglaodiaptomus forbesi f					
Leptodiaptomus ashlandi m	0.78	3.13	1.57	3.05	5.10
Leptodiaptomus ashlandi f	2.91	7.04	10.99	14.21	23.47
Skistodiaptomus pallidus m					
Skistodiaptomus pallidus f	0.11				
Skistodiaptomus reighardi m					
Skistodiaptomus reighardi f					
Leptodiaptomus sicilis?			1.57		
Total Calanoids	4	14	16	22	34
Cyclopoids					
Cyclopoid immatures	0.11	0.39		2.03	1.02
Cyclopoid Unident					
Acanthocyclops vernalis					
Diacyclops thomasi	7.06	19.95	26.68	23.86	26.53
Eucyclops agilis/speratus					
Mesocyclops edax	0.11		0.79		
Paracyclops fimbriatus poppei				0.51	
Total cyclopoids	7	20	27	26	28
Harpacticoids (Unidentified)		0.39		2.03	2.04
Cladocerans					
Cladoceran unidentified					
Cladoceran immatures					2.04

GCES November 1985

Alona affinis				0.51	1.02
Alona guttata					
Bosmina longirostris		0.39		2.03	
Chydorus sphaericus					
Daphnia unidentified					
Daphnia galeata mendotae	0.11			0.51	
Daphnia parvula					
Daphnia pulex			0.79	0.51	
Diaphanosoma birgei	0.11				1.02
Leydigia quadrangularis					
Pleuroxus aduncus					
Pleuroxus denticulatus					
Total cladocerans	0	0	1	4	4
Amphipods					
Gammarus lacustris	1.01	0.39			
Other					
Hydras	0.45	2.74	8.63	1.02	2.04
Large insect larvae	4.59	3.52	9.42	14.21	14.28
Ostracods				0.51	
Rotifers					
Tardigrades		0.39		1.52	3.06
Molluscs	0.56				
Total Organisms	18.36	42.25	62.78	83.76	95.91

GCES November 1985

GCES November 1985					
Inclusive Dates					
Trip Agency					
River Mile	68	77	77	77	77
Location	Tanner	Above Hance	Above Hance	Above Hance	Above Hance
Position	MC/ Raft	Left/ rocks	Left bank/raft	Left bank/raft	Left bank/raft
Depth	0-2 meters	Surface	0-2 meters	0-2 meters	0-2 meters
Date	15-Nov-85	16-Nov-85	16-Nov-85	16-Nov-85	16-Nov-85
Time	14:29:45	9:46:30	10:15:00	14:00:00	18:00:00
Volume Filtered m3*	1.99	10.20	0.68	0.78	0.83
TAXA/SPECIES #/m3					
Copepods					
Calanoids					
Nauplii	6.04		7.30	5.10	12.12
Calanoid Unidentified					
Diaptomus imm.	1.51	0.20		2.55	1.21
Diaptomus unid.			1		
Aglaodiaptomus clavipes m		0.10			
Aglaodiaptomus clavipes f					
Aglaodiaptomus forbesi m		0.10			
Aglaodiaptomus forbesi f					
Leptodiaptomus ashlandi m	3.02			5.10	3.64
Leptodiaptomus ashlandi f	7.04	0.78	5.84	15.31	12.12
Skistodiaptomus pallidus m	0.50				
Skistodiaptomus pallidus f	0.50				
Skistodiaptomus reighardi m					
Skistodiaptomus reighardi f					
Leptodiaptomus sicilis?					
Total Calanoids	13	1	7	23	17
Cyclopoids					
Cyclopoid immatures	1.51				1.20
Cyclopoid Unident					
Acanthocyclops vernalis					
Diacyclops thomasi	15.09	1.08	24.83	30.62	30.30
Eucyclops agilis/speratus					
Mesocyclops edax					
Paracyclops fimbriatus poppei					
Total cyclopoids	17	1	25	31	32
Harpacticoids (Unidentified)	1.51		1.46	6.38	3.64
Cladocerans					
Cladoceran unidentified					
Cladoceran immatures	1.01				

GCES November 1985

Alona affinis	0.50		1.46	1.28	1.21
Alona guttata					
Bosmina longirostris	2.01		2.92	1.28	4.85
Chydorus sphaericus					
Daphnia unidentified					
Daphnia galeata mendotae					
Daphnia parvula					
Daphnia pulex					
Diaphanosoma birgei					
Leydigia quadrangularis	0.5				1.2
Pleuroxus aduncus					
Pleuroxus denticulatus					
Total cladocerans	4	0	4	3	7
Amphipods					
Gammarus lacustris	0.50	0.39			
Other					
Hydras	4.02	1.18	1.46	5.10	1.21
Large insect larvae	9.56	1.18	2.92	7.66	7.27
Ostracods					
Rotifers					
Tardigrades	1.01		5.84	12.76	19.39
Molluscs					
Total Organisms	55.84	5.00	55.03	93.14	99.37

GCES November 1985

GCES November 1985				
Inclusive Dates				
Trip Agency				
River Mile	77	77	132	132
Location	Above Hance	Above Hance	Deubendorff	Deubendorff
Position	Left bank/raft	Left bank/raft	Edge rocks	MC/raft
Depth	0-2 meters	0-2 meters	Surface	Surface
Date	16-Nov-85	17-Nov-85	22-Nov-85	22-Nov-85
Time	22:00	6:05:00	10:12	11:12
Volume Filtered m3*	0.83	0.81	?	?
TAXA/SPECIES #/m3				
Copepods				
Calanoids				
Nauplii	13.33	7.42	31	19
Calanoid Unidentified				
Diaptomus imm.		1.24	18	5
Diaptomus unid.				
Aglaodiaptomus clavipes m				
Aglaodiaptomus clavipes f				
Aglaodiaptomus forbesi m				
Aglaodiaptomus forbesi f				
Leptodiaptomus ashlandi m	3.64		13	7
Leptodiaptomus ashlandi f	4.85	8.66	24	14
Skistodiaptomus pallidus m				1
Skistodiaptomus pallidus f		1.23	2	
Skistodiaptomus reighardi m				
Skistodiaptomus reighardi f				
Leptodiaptomus sicilis?				
Total Calanoids	8	11	57	27
Cyclopoids				
Cyclopoid immatures		1.23	4	1
Cyclopoid Unident				
Acanthocyclops vernalis				
Diacyclops thomasi	31.52	21.03	98	53
Eucyclops agilis/speratus				
Mesocyclops edax			2	
Paracyclops fimbriatus poppei				
Total cyclopoids	32	22	104	54
Harpacticoids (Unidentified)	4.85	1.24	15	10
Cladocerans				
Cladoceran unidentified				
Cladoceran immatures	1.20	1.24	2	1

GCES November 1985

Alona affinis	2.42	2.47	5	3
Alona guttata				
Bosmina longirostris		3.71	8	15
Chydorus sphaericus				
Daphnia unidentified	2.41	1.23		1
Daphnia galeata mendotae				
Daphnia parvula				
Daphnia pulex				
Diaphanosoma birgei				1
Leydigia quadrangularis			1	
Pleuroxus aduncus				
Pleuroxus denticulatus			1	
Total cladocerans	6	9	17	21
Amphipods				
Gammarus lacustris				
Other				
Hydras	2.42		5.00	3.00
Large insect larvae	8.48	7.42	32	9
Ostracods			2	1
Rotifers				
Tardigrades	15.76	16.08	34	44
Molluscs				
Total Organisms	90.88	74.19	297.00	188.00

APPENDIX II

Hourly discharges from Glen Canyon Dam for the GCES collections of December 1984-January 1985, October 1985, and November 1985, together with time and river mile of each sample

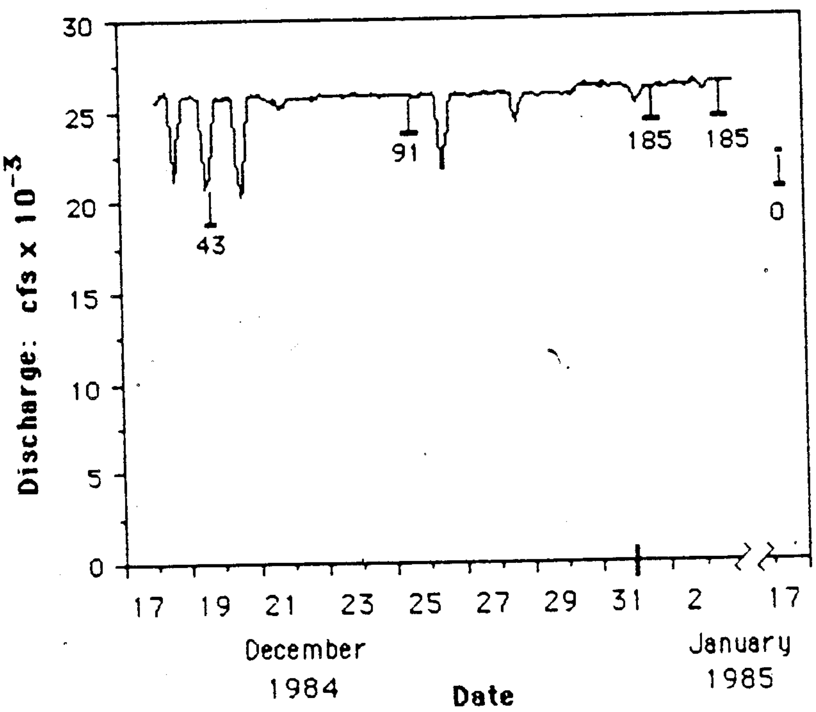

Figure 1. Hourly releases from Glen Canyon Dam penstocks between 18 December 1984 and 2 January 1985; the 17 January 1985 discharge is also shown. A five hour running average has been applied to smooth the hourly discharges. The inverted Ts and adjacent numbers denote the time and river mile at which the sample was taken. No attempt has been made to incorporate lags to account for actual flows at the time and place of sampling.

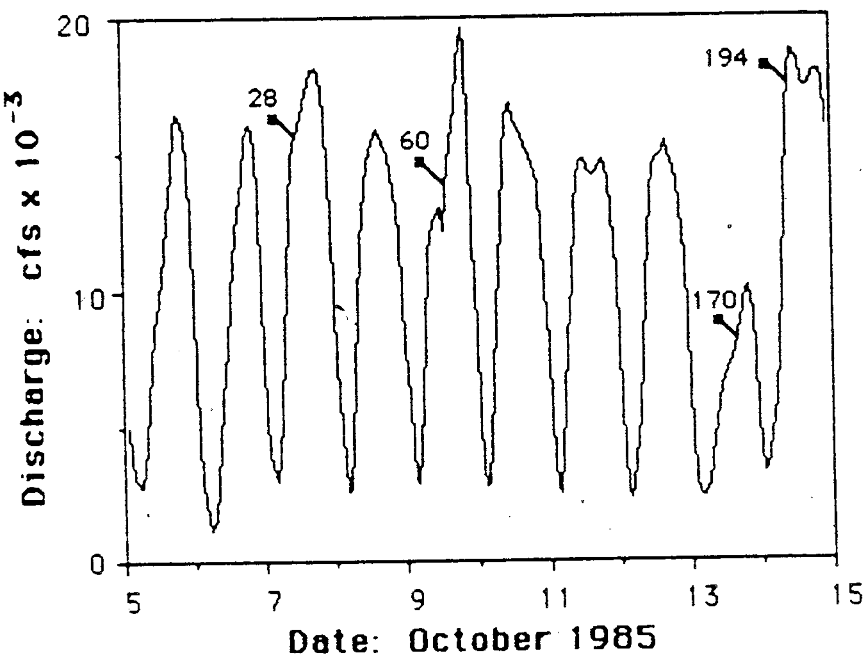

Figure 2. Same as Figure 1, except for the period 5 through 15 October 1985.

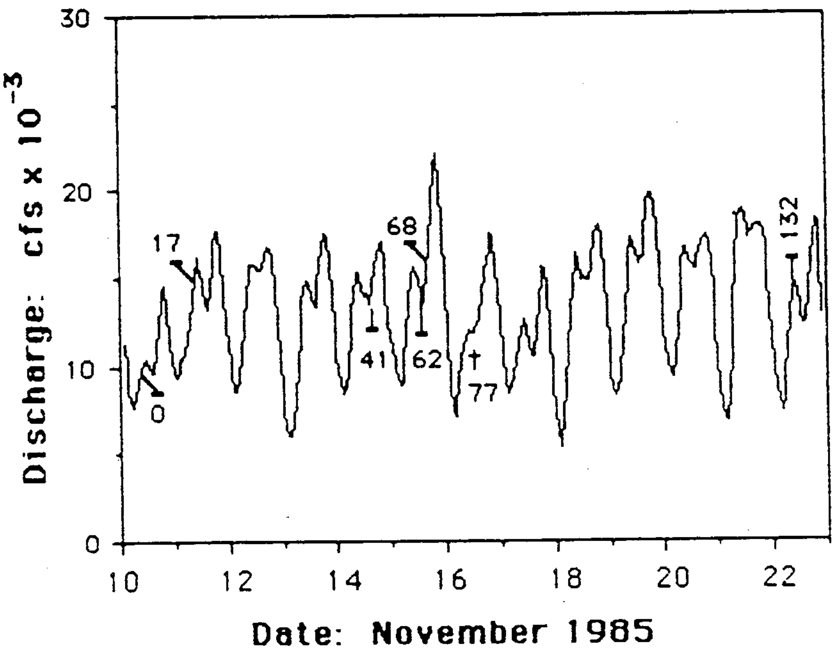

Figure 3. Same as Figure 1, except for the period 10 through 23 November 1985. The cross symbol denotes the time at which the 20 hour sample series was taken above Hance Rapids.